Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections

Edited by
Janet Waddington
and
David M. Rudkin

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Preface

This publication comprises the papers and posters presented at the second Workshop on Care and Maintenance of Natural History Collections, held at the Royal Ontario Museum, Toronto, Ontario, Canada, on 22 to 23 May 1985. Over 100 participants from across Canada, the United States, and the United Kingdom attended a full program of 23 oral and 10 poster presentations that ran the full gamut of philosophical and practical aspects of acquisition, preparation, preservation, documentation, and storage of geological and biological specimens. The large number and wide geographic representation of participants underline the ongoing need for gatherings of this nature.

No function can succeed without a great deal of help behind the scenes. The organizers are grateful to the following for their assistance: David Barr, associate director—curatorial, ROM, for providing space for the talks, coffee breaks and poster sessions, and reception; the Members' Volunteer Committee, ROM, for their assistance with registration, coffee breaks, and the reception; several ROM staff members for their help in organizing, particularly Peter Fenton, Ross MacCulloch, Deborah Metsger, and Rein Jaagumagi.

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In memory of Gordon Gyrmov, Chief Technician in the Department of Vertebrate Palaeontology, Royal Ontario Museum, from 1962 to 1986

CONSERVING NATURAL HISTORY COLLECTIONS: SOME PRESENT PROBLEMS AND STRATEGIES FOR THE FUTURE

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ABSTRACT—Natural history collections in museums around the world represent the results of centuries of collecting and systematic research. The value of these collections is poorly understood by the public and, more importantly, by the politicians responsible for the funding of most museums. Funding for the sciences in museums in general, and for natural history museums in particular, is significantly lower than that granted to the arts. As a result, natural history collections, even in large national institutions, are threatened with deterioration because of poor curation and inadequate storage conditions. Research and development of better methods for the preparation and preservation of natural history materials in museums is necessary in order to preserve our heritage of collections and to make the most efficient use of diminishing funds. Strategies for improving care of natural history collections include development of improved curation procedures, increased public awareness of the value of the collections, and training programs for specialists in the conservation and collection management of natural history materials.

Introduction

The collection of natural history specimens began in earnest during the late 17th to the early 18th century. Today there is a growing awareness in museums throughout Europe, North America, and Australia of both the enormous size and the irreplaceable cultural value represented by natural history collections.

Natural history collections differ in several respects from other cultural collections. They represent neither the history nor the technology of a nation, but the distillation of man's knowledge of his planet. They exist outside cultural and national barriers for all to observe and learn from—a "global resource" (Challinor and Kerby, 1984). Over the past 50 years however, they have not received the special care and attention they deserve—certainly not the cosseting afforded even fairly trivial art objects.

There are several reasons for this state of affairs, most of which relate to public awareness of the value of collections. Natural history collections are rarely assigned the tangible financial worth of art objects; their scientific value has always been considered paramount, and collection custodians have fought to retain this situation. Ricklefs (1980) and Bryant (1983) have suggested that the techniques of taxonomy are changing and that natural history museum researchers are no longer in touch with their benefactors, the public. These authors perhaps think that the type of research undertaken is beyond the grasp of the public. This is a departure from the non-elitist popularization of science carried out by museums even 25 years ago. In addition, the issues publicized by many natural history museums tend to divert public attention from the state of their collections. Little attempt has been made to apply the concept of added value to the impact of natural history collections on society (Anderson, 1973). More importantly, their worth is not recognized politically (Irwin et al., 1973; Banks, 1979; Bryant, 1983). This is evident in the comparison of levels of funding for science museums and arts museums (Table 1). In the United Kingdom at least ten times more is spent on the arts than on sciences. Spending on natural history collections represents only a fraction of the overall science budget.

State of Collections

In the absence of any comprehensive international survey of natural history collections, it is estimated that worldwide holdings exceed 1500 million specimens and are growing at a rate of perhaps 50 million specimens a year. A significant proportion of this vast resource is in poor condition or actively deteriorating, even in eminent national collections. The work of over 300 years of collection and research is in peril.

An example of the size of national collections is seen in the British Museum (Natural History) in London. The Zoology Department alone houses some 35 million specimens stored on over 80 km (50 mi) of shelving. This museum is one of the better endowed, with 65 professional staff in the department, or an average of one staff member for each half million specimens on just under a mile of shelving. Thus the impossibility of giving even a small proportion of the collection the standard of care and conservation required can be appreciated.

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Table 1 **Comparison of levels of funding between science museums and arts museums in the United Kingdom**

Total United Kingdom expenditure on natural history collections (all types of museums—estimated 1985)	£20 million
Percentage allocated to natural history collections	
—out of total civil research budget	1.6
—out of total public expenditure budget	0.01
Percentage allocated to arts museums	
—out of total arts budget	25
—out of total public expenditure budget	0.25[1]

[1] Wilding (1985) gives a figure of slightly less than 0.5%; however, this includes about 0.25% expenditure on public libraries and the performing arts.

Table 2 **Status of natural history collections in United Kingdom museums**
The figures shown are approximations obtained from (a) the Biology Curators' Group (in press) and (b) Doughty (1981); see also Museums Association Working Party on Natural Science Collections, Part 2 (1985) for numbers of curatorial staff available and for some limited data on the state of biological collections.

Number of museums in the United Kingdom	604[1]	
	(a) biological collections	(b) geological collections
Number of museums	254	280
Number of specimens	>100 million	>20 million
Number of specimens in national collections	>70 million	>17 million
Number of museums with natural history curators		
—full time	50	44
—part time	25	51
Specimen condition		
—indifferent	40%	56%
—decaying	20–25%	30%

[1] The United Kingdom Museums Association (Bromley, 1985) lists 604 current institutional members. There are however more than 3000 "museums" in the United Kingdom including private museums, learned societies' collections, etc.

The museum profession is becoming aware of the magnitude of the problem. In both the United States (through the activities of bodies such as the Association of Systematics Collections) and the United Kingdom (through the activities of the Biology Curators' Group, the Museums Association, and the Geological Curators' Group), surveys of the state of collections have been started and some results are available (Table 2). If these figures are representative of worldwide conditions, and it is most likely that natural history collections in countries with extreme climates are in worse condition than those in the United Kingdom, then it is entirely possible that up to a third of all collections or 500 million specimens are actively decaying in museums around the world.

Poor storage conditions (Fig. 1) lead sooner or later to serious decay problems for both biological (Fig. 2) and geological (Fig. 3) materials. The conditions and specimens depicted here were found in foremost institutions in the early 1980s; such conditions undoubtedly exist in many museums worldwide. A prime media message today concerns the importance of preserving species and habitats that are under threat of destruction. We appear to have forgotten that, having caused the extinction of a number of species in the past, we have also in some instances lost all record of their existence. Few museums now possess complete specimens of the dodo or passenger pigeon; many recently extinct plant and insect species have no extant remains in our collections. How many species are now passing into extinction without even our knowledge of their existence? We may have to wait for their fossil remains to learn more about them. If habitat destruction continues at its present alarming rate, it may be that by the middle of the next century the majority of species alive today will be represented only by their remains in museums—or will they?

The very fact that biological material must be "fixed" or "preserved" before being worked on in the museum brings about a false sense of security. The techniques of

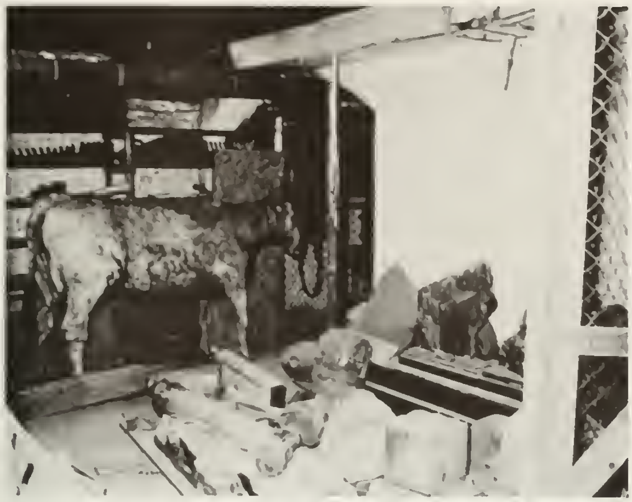
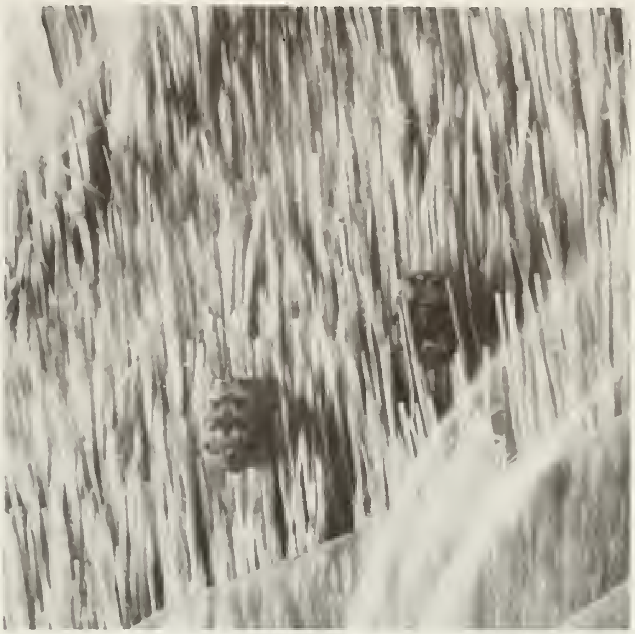


Fig. 1. Forgotten in the basement.

Fig. 2. Dermestid beetles (*Anthrenus sarnicus*) looking for their next home on an antelope mount.



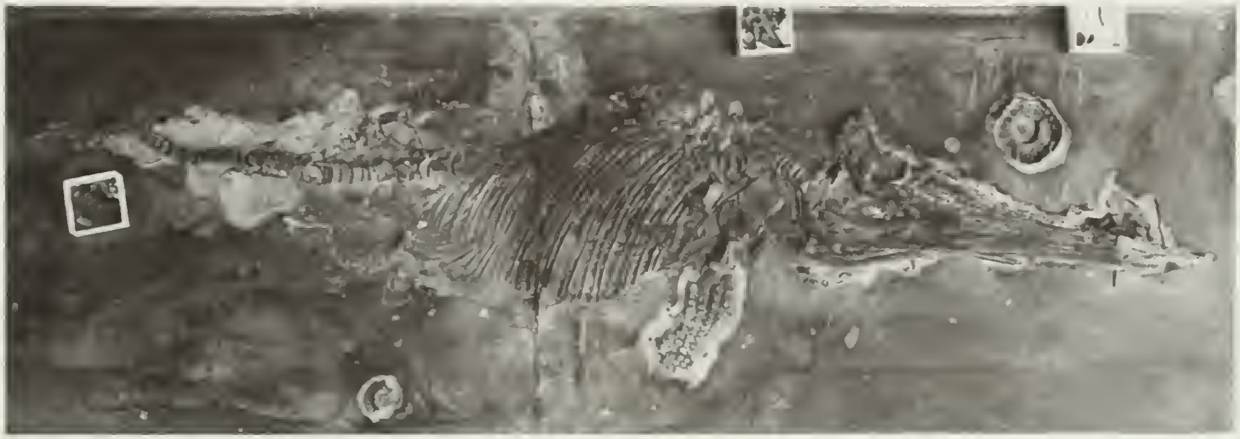


Fig. 3. Jurassic ichthyosaur showing effects of pyrite oxidation and shale delamination caused by storage in poor environment.

preservation are not designed to maintain specimens eternally. Wet-preserved biological material will probably survive in usable condition for 50 to 70 years, at best. Standard taxidermic preparations up to the 1950s used highly toxic materials such as mercury and arsenic to discourage pests. Few such specimens have survived more than 100 years. Today there is a tendency to use pesticides of unproven efficacy and fumigation as a matter of course. Synthetic materials such as Edolan, polyurethane, silicones, and epoxy-based plastics are commonly used in taxidermy, and a range of mixtures of preservatives are used in wet preservation (Harris, 1984). Little research has taken place on the development of new techniques and materials that might be used in the preservation of natural history specimens. Much appears to have been borrowed from the field of pathology, in which short-term preservation is the general requirement, or from archaeology and antiquity conservation and restoration, in which the materials are generally dissimilar from those in natural history collections (with the exception of the geological sciences). Many techniques are so steeped in tradition that today's practitioners often have no understanding of their basis.

Table 3 Costs of collection management in a large United Kingdom natural history museum

Aspect of Management	Cost
Cost of accession per specimen	£10
Maintenance cost per specimen per year	£ 0.14
Maintenance cost per specimen per year for environmentally susceptible specimens	£ 0.85
Cost per specimen to treat/conserve/store (staff and materials; palaeontology specimens, 1983)	£20

Collection Management Costs

Given the scarcity of funding, museums must be aware of the costs of accessioning, treating, and conserving specimens. Anderson (1973) estimated the cost of accessioning new mammal specimens in the National Museum of Natural History (Smithsonian Institution) at $10 (U.S.) with maintenance costs of 24 cents (U.S.) per year. These costs are now significantly higher. Increasing numbers of museums are finding their budgets totally inadequate even to maintain the fabric of their buildings, their exhibits, and their security, let alone to care for their collections. In terms of value for money, collections held in second-rate or poorly controlled storage conditions are a poor investment for the future. The costs of conservation per specimen will usually far exceed initial accessioning costs. Table 3 gives some data on the costs of collection management in a large United Kingdom natural history museum.

In the United Kingdom the total investment in specimens (at 1983 costs) is approximately £1.3 billion; the annual cost of upkeep is in the region of £13 million, with those specimens in environmentally controlled storage (probably less than 1 million in total) costing a further £1 million. The total number of specimens actually requiring controlled storage probably exceeds 15 million. With more than 30 million specimens needing treatment (Table 2) the total cost of rescue would be over £500 million. There are at present in the United Kingdom probably fewer than 15 museum staff members, including taxidermists, with any experience in natural history specimen conservation. Probably less than £100 000 per year is spent on natural science conservation, or about 0.5% of the budget for natural history museums. By comparison, the United Kingdom has over 750 conservators in art and archaeology, spending 15 to 20 million pounds on the conservation of objects or about 10% of the total museum budget.

Priorities for the Future

Over the past two decades, research into the problems of conserving different types of natural history material has grown, with a few universities and conservation research departments developing an interest. Table 4 indicates some of the areas in which progress is being made. There are many additional areas which would benefit from further fundamental research: the fixation of biological materials, histology, the effects of past treatments on specimens, and the use of fumigants, to name but a few. Formaldehyde, used worldwide in museums as a primary fixative, is now known to be hazardous to humans. The use of ethanol and isopropanol for long-term storage has many problems (Harris, 1984). Steedman (1976) published an objective and detailed review of the principal fixation and preservation methods used on zoological material, recommending that international and national funding be provided to facilitate research into improved techniques. To date little has been achieved.

The use of fumigant and vapour-phase insecticides in museums has recently attracted attention (Endrody-Younga and Baumok, 1984; Edwards, Bell, and King, 1980; Stansfield, 1985). Concerns about the human toxicity and efficiency of insecticides and the effects of long-term exposure to chemicals on specimens have led to consideration of alternative methods of control (Jessup, 1984). Stansfield (1985) suggests that much more research is needed into such questions as the scale of pest intrusions into collections, the types of pest present, the effects of treatment on different pests, the effects of pesticides on objects, and the determination of safe working procedures for both treatment and subsequent use of collections. Effective housekeeping combined with the use of insect-specific treatments such as insect juvenile hormones or certain vapour-phase pyrethroids or pheromones could lead to the eradication of pest problems in natural history museums before the end of the century.

With regard to the backlog of conservation and curation problems in natural history collections, little can be achieved until priority schedules are drawn up. Bandes (1984) drew up a schedule of priorities and recommendations for arts and antiquities collections for the American Association of Museums' Collection Need Project. The strategies are equally applicable to natural history collections:

Table 4 Status of research on natural history collection conservation

Type of Problem	Status of Research and Development
Pest control	Current projects in United Kingdom universities and museums (Armes, 1984); report by ASC; control programmes in United States and Canadian museums; research at CCI
Freeze storage	Developmental work in Australia and the United Kingdom
Freeze drying	See Harris (1984); Romero-Sierra (this volume)
Colour stability and stability of skins	Current university projects in the United Kingdom; work at CCI
Replication methods	Research in United Kingdom and European museums
Mineral stability	See Waller (1980); Howie (1979)

1) establishment of improved environmental conditions,
2) documentary control of collections through adequate curation,
3) conservation of objects,
4) use of collections to expand knowledge through research,
5) increased public awareness of collections.

Particular stress is placed on the need to upgrade the education and training of collection managers, collection technicians, and conservators, and to enhance the channels of communication between conservators and other museum professionals. The true natural history collection conservator does not yet exist; however, meetings such as this are further steps in the right direction. Now more than ever natural history collection specialists are communicating with conservators in other fields and it may not be long before the profession benefits from its own properly trained conservators and collection managers. Let us hope it is not too late.

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CURATORS AND NATURAL HISTORY COLLECTIONS: HAVE WE BECOME ISLANDS IN SCIENCE?

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Abstract—For many biologists, natural history museum curators and their collections have become insignificant islands in science, separated from the larger body of scientific endeavour. Data from a survey of recent journals supports this contention and emphasizes the problem; a relatively small proportion of scientists makes use of collections and although some groups of researchers (most notably ecologists and parasitologists) make frequent field collections, little of this material is reported as deposited in permanently maintained collections. If natural history collections are to prosper and their adequate curation be assured, curators and collections managers must take an active role in communicating the value of their collections to the non-curatorial scientist. One approach, and a relatively low-cost one, is the preparation of a slide or video package on the role of collections in research. Such a package, with accompanying text, is currently being developed as a joint project of the Natural Science and Education departments of the New Brunswick Museum.

Introduction: The Root of the Problem

> The Museum tradition [in ornithology] is dying. The [three million or so] skins, skeletons and anatomical specimens in collections [in the United States] have largely served their intended purpose in the pursuit of taxonomic and biogeographical investigations. (Robert E. Ricklefs, 1980)

> The Museum tradition [in ornithology] is not dying—it is being killed; strangled by the pervasive attitude that only theoretical and experimental approaches to biology are valid, by university departments that have eliminated evolutionary or morphological biology from their curricula and by museum administrators who fill curatorships with ecologists, ethologists and chemists, while their collections languish. (Storrs L. Olson, 1981)

The arguments of Ricklefs and Olson suggest that in the scientific community opinions on the value of natural history collections may be widely divergent. That institutions housing collections are understaffed and underfunded and that significant collections are in danger of deterioration has been the subject of frequent and recent discussions (Conference of Directors of Systematic Collections, 1971; Irwin et al., 1973; Biological Council of Canada, 1977; Zoological Museum, 1978; Peden and Carcasson, 1979; McKillop, 1980; Barlow and Flood, 1983).

While few biologists probably consider collections to be without value, my own experience suggests that many biologists, perhaps the majority, remain largely uninformed of the nature and value of collections. Here I would like to examine briefly the roots of this problem, and suggest what I believe are some of its implications.

The roots of the dilemma facing those charged with curating natural history collections may be in part historical. Even the term "natural history" is fraught with the overtones of the less rigorous and less sophisticated scientific past. Farber (1982) notes that common usage of the word biology dates to the early 1800s. Its use signified the rise of what was perceived to be a new approach to the study of the living world—an approach that was basically physiological and that involved the study of processes such as respiration, digestion, and nutrition.

Practitioners of biology saw their endeavours as something quite distinct from those of natural historians who were concerned with the classification and description of organisms. While physiology had its roots in chemistry and medicine (Farber, 1982) and drew on the precision instruments and methodologies of the exact sciences, museum research in the sciences traces its ancestry through a sometimes motley collection of curios, monstrosities, and "natural history cabinets" of uncertain pedigree acquired by 18th and 19th century explorers and by both amateur and professional collectors.

For the Victorian naturalist, nature was the handwork of God (Berger, 1983). The examination of collections revealed patterns that displayed his wisdom, power, and goodness. The Darwinian revolution of the late 19th century, however, produced a shift in the emphasis of natural historians. While collections continued to be accumulated at an accelerating rate, such accumulation became part of the effort to reveal and understand the evolutionary process. To a large degree this is still the

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case, as investigators study the biogeography, anatomy, osteology, and external form of specimens in collections. The development of additional uses for biological collections in such diverse fields as toxic chemical research, botanical chemotaxonomy, histology, and cytology, and as reference materials for archaeological analysis of faunal remains and studies of vertebrate food habits (Stains, 1959; Mori, 1970; Quay, 1974; Rick, 1975; Cash and Bogart, 1978; Olsen, 1979; Coradin and Giannosi, 1980) should amply demonstrate the usefulness of collections as a scientific resource.

A Look at the Literature

Perhaps my encounters with curatorially ill-informed biologists are unique. I think not. However, to provide a more objective assessment of the attitudes of the scientific community towards the role and value of natural history collections in research, I have surveyed some of the recent scientific literature. I examined all papers (N = 1350) in the recent volumes of each of 12 selected journals (Table 1). I chose these journals because they were available to me and also because they report a wide spectrum of research in the biological sciences, although in some cases they are restricted to certain taxa (e.g., *Auk* is an ornithological journal). The results should not be considered representative of the biological sciences as a whole, but I believe they do place an accurate emphasis on aspects of the problem.

If we look at Figure 1, we find that the proportion of researchers consulting collections relative to those who do not is small, only 12.7% in the papers I examined. It is true, and has been noted previously (Ricklefs, 1981), that there has been a decline in the proportion of research projects based on specimens, relative to those not requiring collections. Nevertheless, some authors have suggested that the actual number of workers who rely on specimen collections for their research has probably not itself declined (Zusi, 1969; Ricklefs, 1981).

Since the papers I examined revealed a mere 2% of scientists not affiliated with museums making use of collections, it is perhaps not surprising that communication between the curating and non-curating scientist has been poor.

The problem is compounded in that only a small proportion of the total scientific community is employed in museums (only 10.7% of the papers I consulted had a senior author affiliated with a museum).

Figures 2–4, not surprisingly, show that taxonomists are the heaviest users of collections and are those doing most of the collecting. Interestingly enough, ecologists and parasitologists, who rarely find it necessary to consult collections, frequently make collections of potential museum value (Fig. 2). In my estimation of what makes a collection of museum value, I have been conservative. I demanded only that the material consist of a series of specimens or a unique specimen (perhaps of biogeographical significance) that traditionally formed part of a museum collection (I did not, for example, include collections of bacteria or protozoans), and that these materials should require no additional preparation on the part of the collector to make them suitable for museum acceptance (i.e., botanical collections that were not pressed and dried in the course of the research were excluded). It is disturbing that in 70.9% of the ecological studies and in 60.8% of the parasitological studies reviewed, in which I deemed collections of museum value were made, the material was not reported as deposited in any institution (Fig. 3). And yet ecologists and parasitologists appear to be doing more than 40% of the collecting (Fig. 2). Undoubtedly, I have wronged some authors. Indeed, some of the material would probably have been of little value in a permanent collection. Nevertheless, I am still convinced that significant numbers

Table 1 Journals consulted to determine use of museum collections

Journal Name	Year	Number of Papers
American Midland Naturalist	1982	98
Auk	1982	111
Australian Journal of Zoology	1982	66
Biotropica	1982	55
Canadian Field-Naturalist	1981	77
Canadian Journal of Zoology	1982	438
Copeia	1982	159
Journal of Mammalogy	1982	129
Journal of Natural History	1982	64
Journal of Zoology (London)	1982	113
Rhodora	1982	30
Systematic Zoology	1980	10
		1350

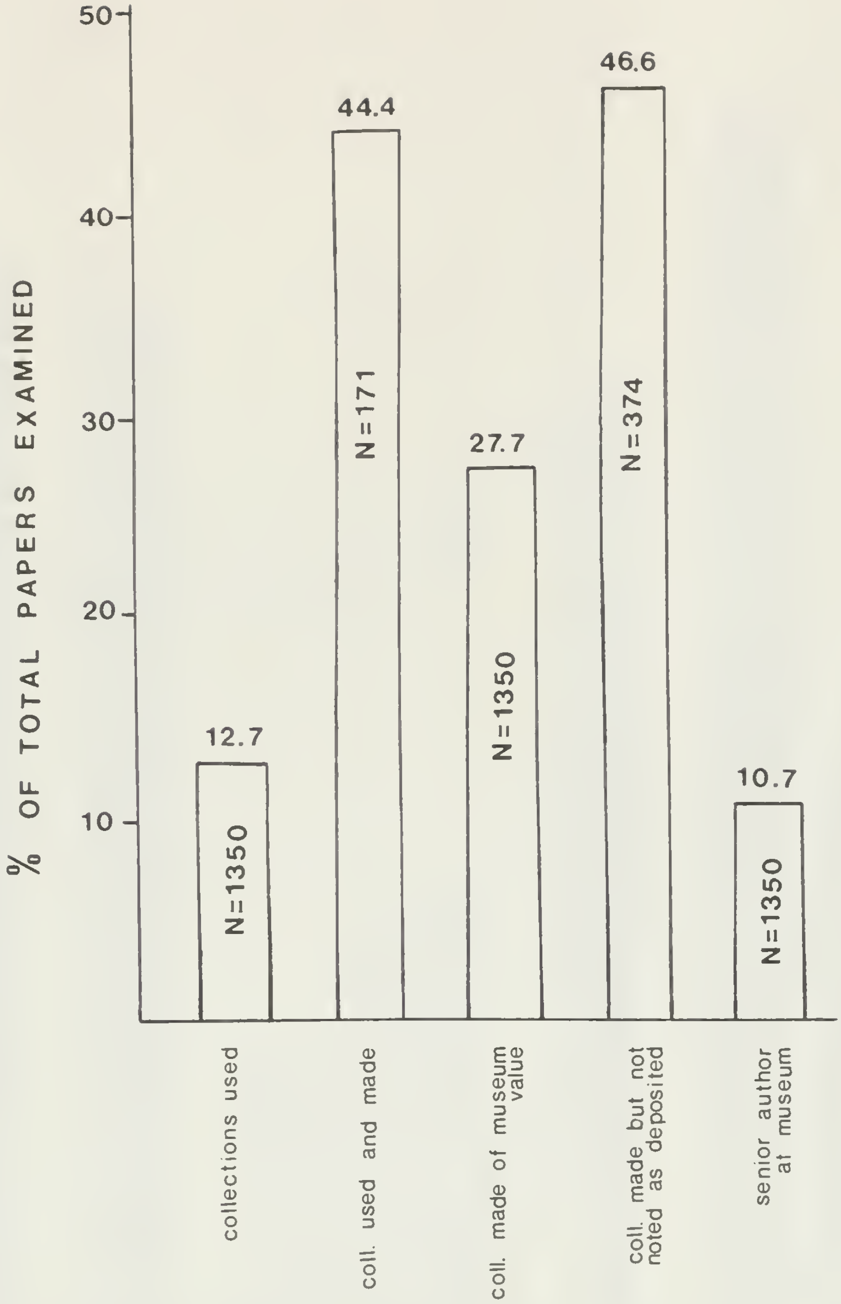

Fig. 1. Data on natural history collections and research in the biological sciences. See text and Table 1 for source of data.

of valuable collections are being lost to science, and at a time when a burgeoning profusion of regulations controlling collecting makes the acquisition of materials all the more difficult (Barlow and Flood, 1983). If deposition goes unreported, one can only assume that collections are either destroyed or, at best, have been left to languish uncurated in a corner, unavailable for further use or verification by other scientists.

Proper identification of the organisms under study is essential in nearly all scientific research. This fundamental fact emphasizes the primary importance of taxonomy and systematics to the biological sciences (Hennig, 1966; Mayr, 1968). Of the total number of consultations of existing collections that I recorded, 56.4% were by taxonomists (Fig. 2). In fact, of the total number of taxonomic or systematic studies I examined, workers either consulted collections, made collections, or did both, in 90.4% of the cases. This emphasizes that maintaining

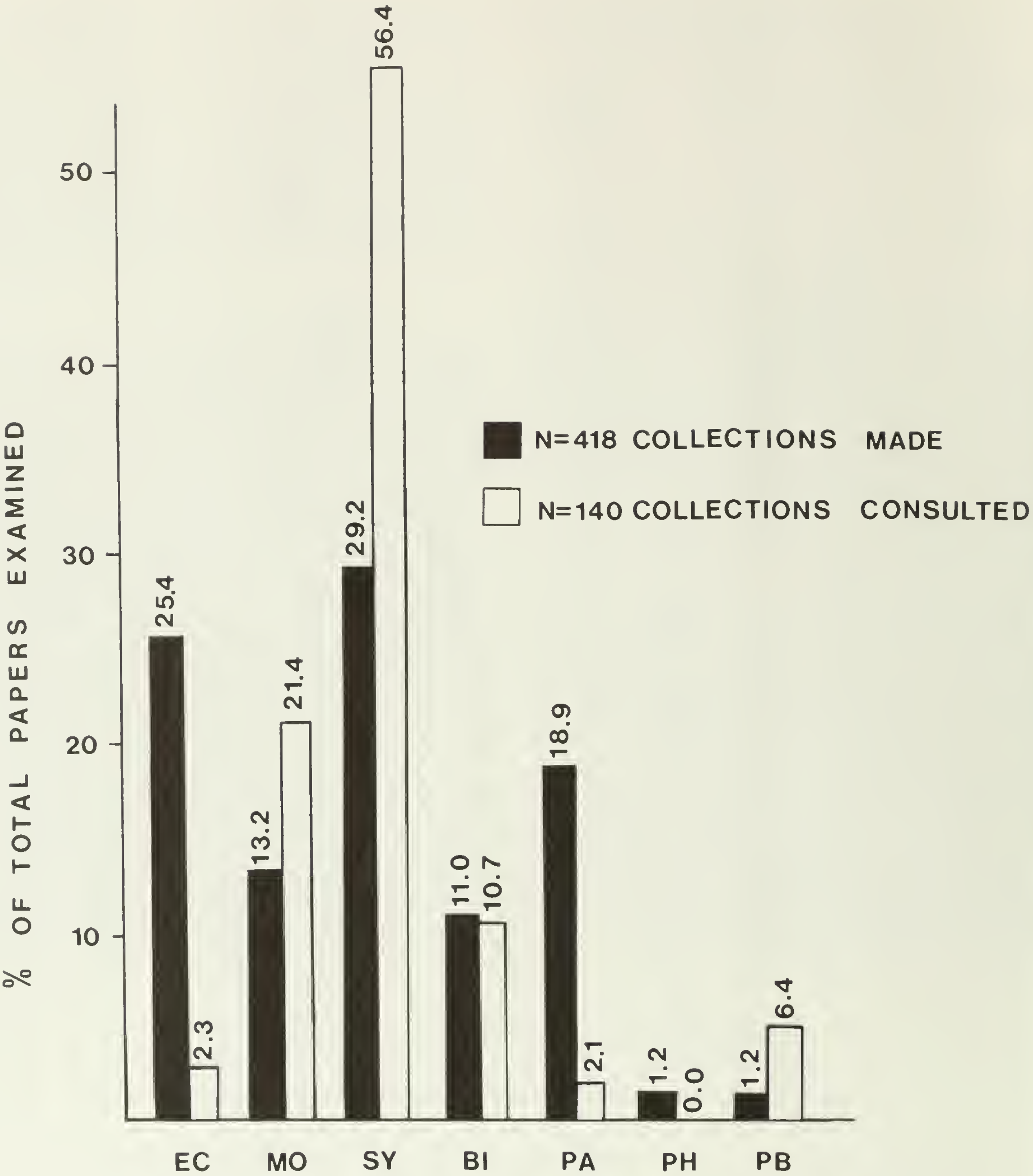

Fig. 2. Percentage of total studies in which collections of museum value were made and percentage of total studies in which museum collections were consulted, arranged by subject matter; EC=Ecology, MO=Morphology, SY=Systematics, BI=Biogeography, PA=Parasitology, PH=Physiology, PB=Paleobiology.

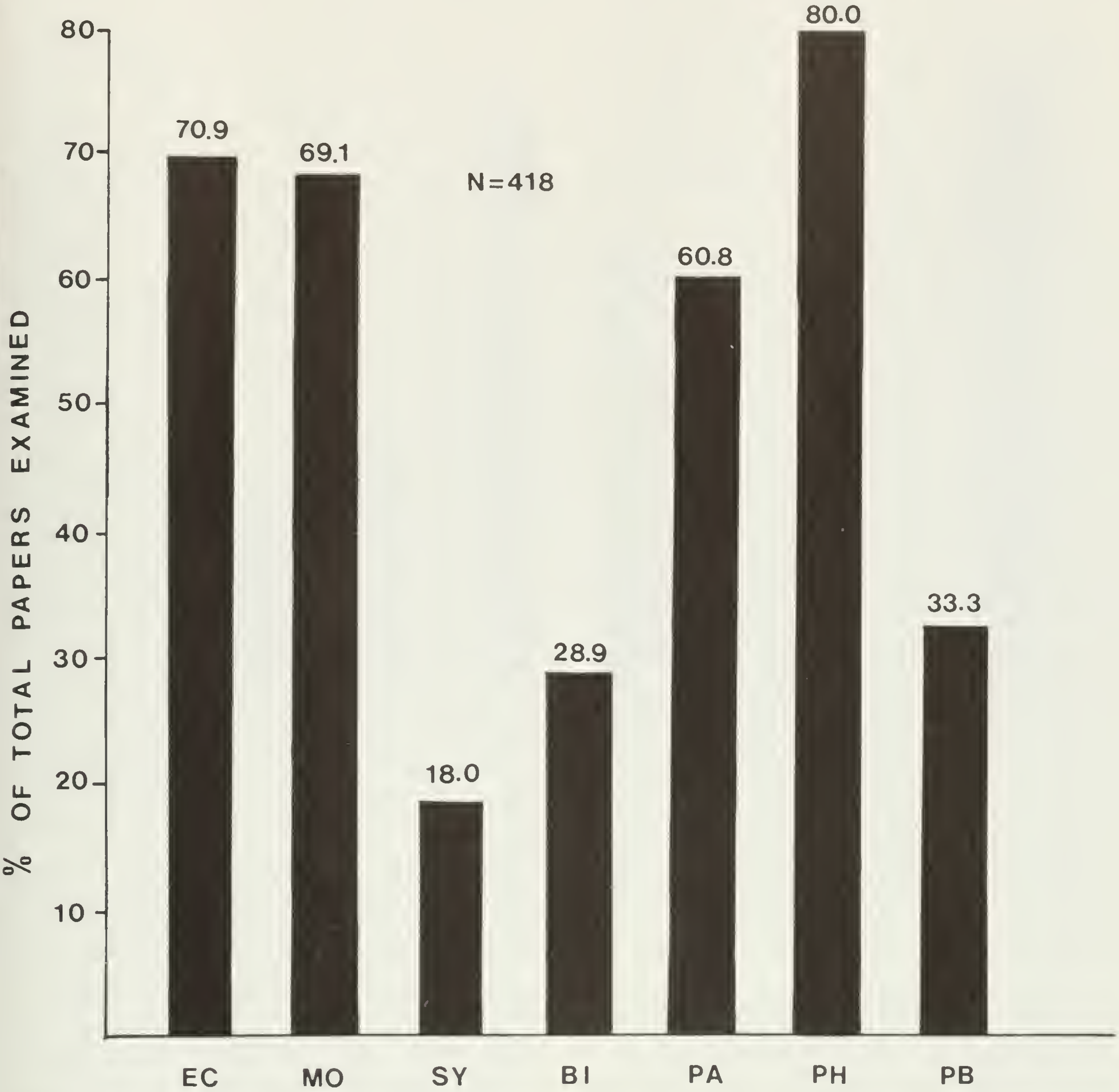

Fig. 3. Percentage of collections of potential museum value which were not reported to have been deposited in a permanently maintained collection. See Fig. 2 for abbreviations.

natural history collections is a vital part of the scientific process. In addition, Figure 2 shows that biological collections are also consulted in morphological studies and to a lesser extent prove useful in the fields of biogeography, paleobiology, ecology, and parasitology. Other fields, some of which I have noted earlier, also occasionally draw on collections—toxic chemical research, for example. There are additional, perhaps more general, reasons for the maintenance of natural history collections upon which I would like to comment. These are the need for *verification* and *documentation*, and the *multiple use of collections*.

It is probably safe to say that scientists, aware of the great importance of type specimens (but see Oldroyd, 1966), nearly always deposit type material in recognized institutional collections. Nevertheless, as I have shown (Fig. 3), scientific journals are rife with examples of research that is not verifiable because investigators have not indicated that they deposited voucher specimens from their study in a permanently maintained collection. If deposition is unreported, one can only assume that no deposit was made. The poor science inherent in this lack of voucher specimens has not gone unnoticed (Darlington, 1971; Robinson, 1975; Smith, 1979). An example with which I am familiar concerns the distribution of the gray treefrog, *Hyla versicolor*, in New Brunswick (McAlpine et al., 1980). In New Brunswick the distribution of *Hyla versicolor* has remained an enigma for herpetologists since 1873, when its presence in the province was first noted. It now appears that it occurs in New Brunswick in a single isolated population confined to one marsh. Distributional records of the species in New Brunswick from 1947, 1955, and 1971, indicating a scattered but wider range, remain unverifiable because no specimens were deposited in a permanent collection, even though collections were made. Recent field studies have not revealed the species at any of the sites mentioned in these records. The first recorded collection of a gray treefrog in New Brunswick was made by herpetologist Philip Cox in 1898. The specimen in question was deposited in a museum and when it was examined 75 years later it was discovered to be a spring peeper, *Hyla crucifer*. This is not an unusual or particularly dramatic example. Those who deal regularly with collections can undoubtedly cite their own tales of woe in attempting to trace material or to verify information.

Verification and documentation are closely related functions. Many are aware of the use of museum collections to document the past incidence of pesticides and heavy metals in the environment (Rick, 1975). As Barlow and Flood (1983) have emphasized, increasing habitat destruction and species extinctions and extirpations all over the world have made the role of collections as biological archives more important than ever before. Biogeographical patterns, toxic chemicals, changes in local patterns of species diversity, and habitats may all be permanently documented in museum collections. In addition, many institutions also house files that augment collections information in the areas of biogeography, ecology, and behaviour, and may include collectors' notes, slides, tape recordings, casts of tracks, etc.

Specimens may also have multiple use and, as analytical techniques become more sophisticated, specimen value can only increase (see, for example, Howell and Butts, 1983). Most biological materials in museums have been collected for the use of taxonomists, but specialists in many other fields are making increasing use of museum specimens. Moreover, museum scientists are now involved in a variety of problems in addition to that of describing new species (Fig. 4). Material collected originally for taxonomic work may later furnish investigators with reproductive, ecological, physiological, or morphological information, as well as with data on environmental contamination.

Recently, Challinor (1983) has remarked on the responsibility of museum curators and collections managers to maintain the data banks (i.e., the collections) under their care. It is true that these individuals are employed to carry out this task. Nevertheless, as I have tried to show, the problems facing curators are compounded by what appears to be a poor understanding in the scientific community of the role and value of biological collections, in spite of their demonstrated usefulness. Poor communication between those scientists collecting specimens and those curating and using collections has been shown by the quantities of material that are collected but apparently never deposited in permanently maintained collections. I suggest that the responsibility for communication among these groups must rest with curators and collections managers.

One approach, and a relatively low-cost one, is the preparation of a slide or video package on the role of collections in research. On occasion I have had the opportunity to address university students, naturalists, and professional biologists on the role and value of natural history collections in research. I have been encouraged to find that a presentation describing the sorts of materials that make up natural history collections and how they are used is generally received as informative and interesting. With this in mind, a slide package with accompanying text is currently being developed as a joint project of the New Brunswick Museum Natural Science and Education departments. Our plan is that such a program may be delivered by Science and Education department staff, as well as volunteers and teachers, to junior and high school science classes, university students, and perhaps even meetings of professional biologists. The topic lends itself well to a variety of approaches. For example, a recent

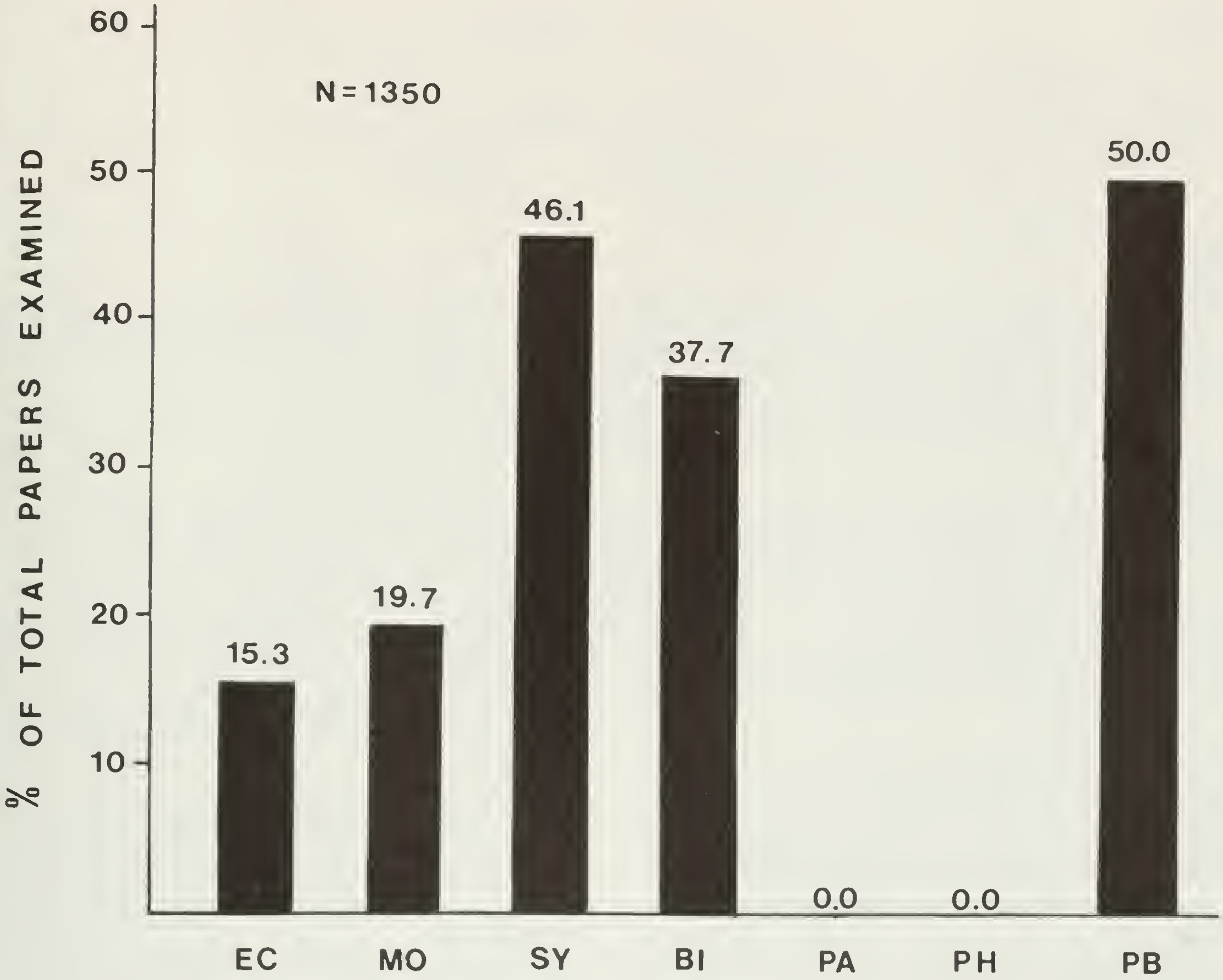

Fig. 4. Percentage of total papers produced in each subject category with senior author using museum address. See Fig. 2 for abbreviations.

meeting of Atlantic Canadian Biologists chose the topic of resource management for their conference. A presentation that considered natural history collections as an irreplaceable, and perhaps threatened, scientific resource was well received.

Bryant (1983) notes that three undercurrents of change threaten biological collections, namely, the continuing phenomenal growth of collections, the impact of inflation on the cost of maintaining collections, and the movement of the biological sciences away from the utilization of collections. While Bryant has identified three problems critical to the future of collections, the fact remains that collections represent a truly irreplaceable scientific resource that is increasingly threatened. I believe that it is imperative that non-curating scientists and potential non-curating scientists (i.e., science students) be informed of the value of collections and that the active support of the scientific community for planned collections growth and maintenance be sought. Much of the responsibility for communicating the value of natural history collections must rest with the keepers of these collections.

Acknowledgements

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MOLD MAKING USING SILICONE CAULKING COMPOUND

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ABSTRACT—High fidelity replicas of most well-stabilized museum objects can be made safely using silicone molds. Silicone caulking compounds formulated without acetic acid are now readily available, inexpensive, and conveniently dispensed from standard 300 ml cartridges. A complete mold can be made in one to three days, depending on complexity. The mold is dimensionally stable, with no discernable shrinkage, and expected mold life is measured in decades. While less elastic than latex rubber, silicone is compatible with all casting resins.

RESUMEN—Réplicas de alto grado de fidelidad de los objetos mejor conservados en un museo pueden ser fabricados sin riesgo utilizando moldes de silicón. Los compuestos selladores de silicone hecho sin acido acetico son fácil de adquirir, económico y convenientemente empacado en cartuchos de 300 ml. Un molde completo puede ser hecho entre uno y tres días dependiendo de su complejidad. El molde es estable dimensionalmente, no presenta contracciones perceptibles, y su vida útil puede ser calculada en décadas. A pesar de ser menos elástico que el látex, el silicone es compatible con todas las resinas empleadas en la fabricacíon de copias.

Introduction

Next to the genuine article, a good replica is the best object for research, display, or teaching. Often the original objects (stone carvings, petroglyphs, etc.) may be endangered by weather or vandals, or specimens and artifacts may be in distant institutions where cost of revisitation is prohibitive. A fast, easy, and safe mold-making material is desirable. The material advocated here is Silicone II,™ or construction grade Gesil N2600,™ both made by General Electric and packed in 300 ml tubes for use with an inexpensive caulking gun. Dow Corning's silicone sealant Silastic 737 RTV™ has recently become available in standard cartridges and compares quite favourably with the General Electric product for the purposes described here. In this article the name Silicone II will be used in a generic way to mean either the General Electric or Dow Corning product, both made without acetic acid.

Silicone II caulking compound has many advantages over latex, alginates such as Jeltrate,™ thiokol rubber and others. Simple molds can be made in two days, more complex ones in three, even allowing for curing time. The material is packed in a sealable applicator and may be purchased almost anywhere in North America. The resulting mold shows no significant shrinkage and has an exceptionally long useful life. Silicone II is harmless to most well-stabilized museum artifactual and fossil material, including wood, bone, ivory, metals, minerals, and rocks. It is compatible with almost all casting materials, such as polyester, epoxy, acrylic, polyurethane, and isocyanates although some, such as epoxy, may eventually damage the mold. There is no problem in making molds from vertical surfaces or even undersides, because the silicone does not run.

Silicone molds are less elastic than those made of latex, and are somewhat more likely to tear unless properly designed and handled with reasonable care. Silicone is also more expensive than latex, but not significantly so, especially considering the short life of latex molds when used with resins. The speed and convenience of silicone also greatly outweigh the advantage of the elasticity of latex. Silicone, in the form of pourable RTV, has long been used, but is expensive and requires an enormous amount of mold material relative to the object itself. These molds are also often clumsy to use and subject to tearing. Alginate molds are short-lived, tear easily, and are unsuitable for resin casting. Latex is an excellent mold-making material, but requires several coats and several days curing time and has appreciable shrinkage. It will yield only a few casts with resins before it deteriorates. Furthermore, because it has a high proportion of water, latex is heavy and bulky to carry on data-collecting trips to other institutions.

Materials

Silicone II is widely sold in hardware and building supplies outlets for caulking. It sets by exposure to

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Table 1 **Measurements of variance between the original and three casts of an ulna of a giant armadillo**
All measurements are in mm.

	Original Dimension	Variances[1] Cast 1	Cast 2	Cast 3	Average[2] Variances	Average % Variance
Length	197.8	+0.6	−0.2	+0.4	+0.27	+0.14
Distal height	41.0	−0.1	−0.1	−0.2	−0.13	−0.32
Distal notch height	48.1	+0.2	+0.1	−0.1	+0.07	+0.14

[1] Mean of two measurements per cast
[2] Mean of all six individual measurements

humidity in the air, a process which can be accelerated by misting and exposure to mild heat (approximately 40°C). The older formulation of silicone caulking compound, which contains acetic acid, also produces excellent molds, but may be objectionable from a conservation viewpoint. It is especially useful, however, when whipped with water to make filler plugs for especially indented portions of the silicone mold.

Silicone II, but not the acetic acid based silicone, may be thinned up to 40% with toluene to improve flow characteristics for the first coat, although this may not be required. Alternatively, one may use General Electric Self-Levelling RTV 161 Silicone, or other similar products. These are expensive but are worth the cost if exceptional surface fidelity is desirable. Dow Corning Silastic 737 RTV flows more readily than General Electric Silicone II and spatulates more smoothly, and is thus easier to work with. For most purposes one or two coats of the undiluted Silicone II caulking material will produce an excellent mold. The thickness should be between two and four millimetres depending on the size of the object. Silicone II should not be applied too thickly, because the material will only catalyze to a depth of about three or four millimetres.

Modelling clays (plasticenes) used with silicone must not be oil-based (e.g., Roma Plastilina™), since these are incompatible. A silicone-based modelling clay (plasticene, e.g., Klean Klay™) gives excellent results.

Silicones have been recognized for many years for producing molds with superior dimensional fidelity. Molds made from latex rubber usually result in casts three to five percent smaller than the originals, and this shrinkage can produce considerable infidelity with large specimens. To test the shrinkage of Silicone II, a mold was made of the ulna of a fossil giant armadillo, and three plaster casts were made during a period of two weeks. Following thorough drying, the casts were measured and results are compared in Table 1. Each dimension was measured twice with a dial caliper accurate to 0.05 mm. The results show variations from the original ranging from +0.6 mm to −0.2 mm, with average variation for the six measurements of only −0.06%. This amount is not statistically significant, and may represent variations in plaster mixes or casting techniques. The Silicone II mold thus showed no practical degree of shrinkage or expansion.

Comparisons were made between samples of General Electric Silicone II and Dow Corning Silastic 737 RTV, using simple methods. Strips of each material 10 cm × 16 mm wide × 4 mm thick, were allowed to air dry for five days. Each was examined for several properties, as follows:

Hardness—The Dow Corning Silastic 737 RTV was appreciably firmer than General Electric Silicone II, as indicated by a Shore "A" hardness of 30 points as against 24 for Silicone II. This property could be advantageous if a firm mold was required.

Stretch and resilience—Each 10-cm strip was stretched by hand, first to 20 cm, then by increments of 5 cm. Measurements were made one minute after each stretching. Both strips returned to their original length after stretching to 25 cm. The Dow Corning 737 RTV sample was less elastic than the Silicone II, and could not be stretched beyond 30 cm. At this point it measured 10.1 cm after 5 minutes, and 10.0 cm after 18 hours. Following repeated stretches to 30 cm the 737 RTV sample tore across the middle. The General Electric Silicone II strip stretched to a maximum of 50 cm and returned to almost its original length at each 5 cm increment. At 50 cm stretch it returned to the original length in four minutes, but tore after repeated stretches to 50 cm.

From these simple tests, it can be concluded that both samples quickly returned to their original lengths after severe stretching, but that the General Electric Silicone II was considerably more elastic.

Tear—Both samples showed surprising resistance to failure from shear, although once torn or cut they failed rapidly. The inclusion of a small piece of gauze or cheesecloth at points where tearing would be expected will prevent tearing.

In summary, both materials tested made excellent molds. The Silicone II molds were more elastic, but the Dow Corning Silastic 737 RTV was easier to apply. The choice between the products may depend on the type of mold required, or the personal preference of the technician. In comparison with natural latex rubber, the General Electric Silicone II actually stretched farther and recovered its original size much faster.

Methods

The techniques for making silicone molds are similar to those for latex, but with some essential differences. Because the silicone sealants are designed to stick to surfaces, they require the use of a mold release agent, usually in the form of a very thin waxy layer. One of the most convenient and inexpensive is PAM,™ available in an aerosol can for coating cooking utensils. An equally useful material can be made from paraffin wax dissolved in naphtha. For vertebrate fossils, a light brushing with paste wax works well. The mold release is a very thin layer, invisible and neutral for most conservational purposes. It may be removed carefully with an appropriate solvent if desired.

The design of the mold is important, and care must be taken to avoid extreme undercuts. Some cheesecloth should be incorporated at points where tearing is liable to occur, but should not interfere with flexibility and normal stretching. Because of its rapid setting, the silicone should be applied to no more than 60 cm^2 at one time, then smoothed with a small flexible palette knife. When applying the silicone directly from the cartridge, care must be taken to avoid gaps between successive passes. The plastic tip of the tube should be cut at an angle of at least 45 degrees.

Because the silicone becomes tacky very quickly, the outside of the mold will be rather streaky so that it tends to adhere to the mother mold. To eliminate this problem, a layer or two of wet toilet paper or similar tissue is applied before making the mother mold. Plaster may be applied directly to this while it is wet. For large molds, fibreglass and polyester resin can be used to make the mother mold, in which case the tissue should first be allowed to dry, or aluminum foil may be substituted.

In designing molds of larger objects to be used for pour casting or slush casting, the sprue hole can be made quite large. The plasticene plug which serves as the model of the sprue is provided with registration pits, before the mold is made. Once the mold and mother molds are complete, the sprue plug is removed and the silicone parts coated with a thin layer of separator (e.g., wax spray). Next, one or more thin (2 mm × 2 mm) strips of plasticene are applied to the wall of the sprue to provide space for vents. The entire walls and bottom of the sprue (i.e., part of the object) are then given one or two coats of silicone and allowed to set. By using this technique, the base of the silicone plug becomes part of the mold, requiring almost no trimming, greatly enhancing the versatility and fidelity of the mold.

The techniques described above are fairly standard. The accompanying illustrations show steps in making a one-piece wrap-around mold and a two-piece mold. The former method is quite adequate for items of relatively simple shape. Essentially, the object is partly embedded in the plasticene, which becomes the model for the flange. Depending on the size of the object and the casting material one can incorporate a sprue, or make small vents, or leave no vents at all. Half of the mold is made, covering all of the plasticene flange and half of the specimen. When the silicone has cured (less than one day), the plasticene is removed and the half-mold and object are turned over. Plasticene is placed under the flange for support, and the face of the flange is lightly coated with a separator, taking care not to permit the separator to encroach on the remainder of the mold. The remainder of the object and the flange are covered with silicone, the latter bonding readily to the other half of the mold. Mother molds of plaster or fibreglass are then constructed in the usual manner. Vaseline (petroleum jelly) may be used as a separator for the plaster since it will not affect the silicone.

The two-piece mold is used for more complexly shaped objects, following standard techniques. By using silicone-based plasticene and silicone sealant, many of the time-consuming steps can be eliminated, and the whole process simplified. In the illustrations (Figs. 1 and 2) a registration groove is shown, close to the specimen. For larger objects, one can use long wormlike pieces of plasticene which are gently pressed into the flange in the same position, but in place of the registration grooves. The diameter of the plasticene ''worms'' should be from 4 mm to 7 mm, depending on the size of the object. When the silicone is placed over these, they form a more or less cylindrical groove. The groove is filled with silicone when the second half of the mold is made. The result is a snap-together joint identical to that at the mouth of a zip-lock plastic bag.

In conclusion, Silicone II caulking compound is the most versatile mold-making material currently available for most museum applications. The combination of easy availability, low cost, convenience, and versatility make it the obvious choice for use in both lab and field applications.

Acknowledgements

The use of silicone caulking compounds was first demonstrated to me by Doris Tischler of Kerrville, Texas, at the meeting of the Society of Vertebrate Paleontology, October 1982. Brian Iwama, technician in the Department of Vertebrate Palaeontology at the Royal Ontario Museum, has tested and modified techniques of silicone molding for a wide variety of objects. Howard Converse, Department of Vertebrate Paleontology at the Florida State Museum, has experimented with various molding and casting techniques, many of which are listed below.

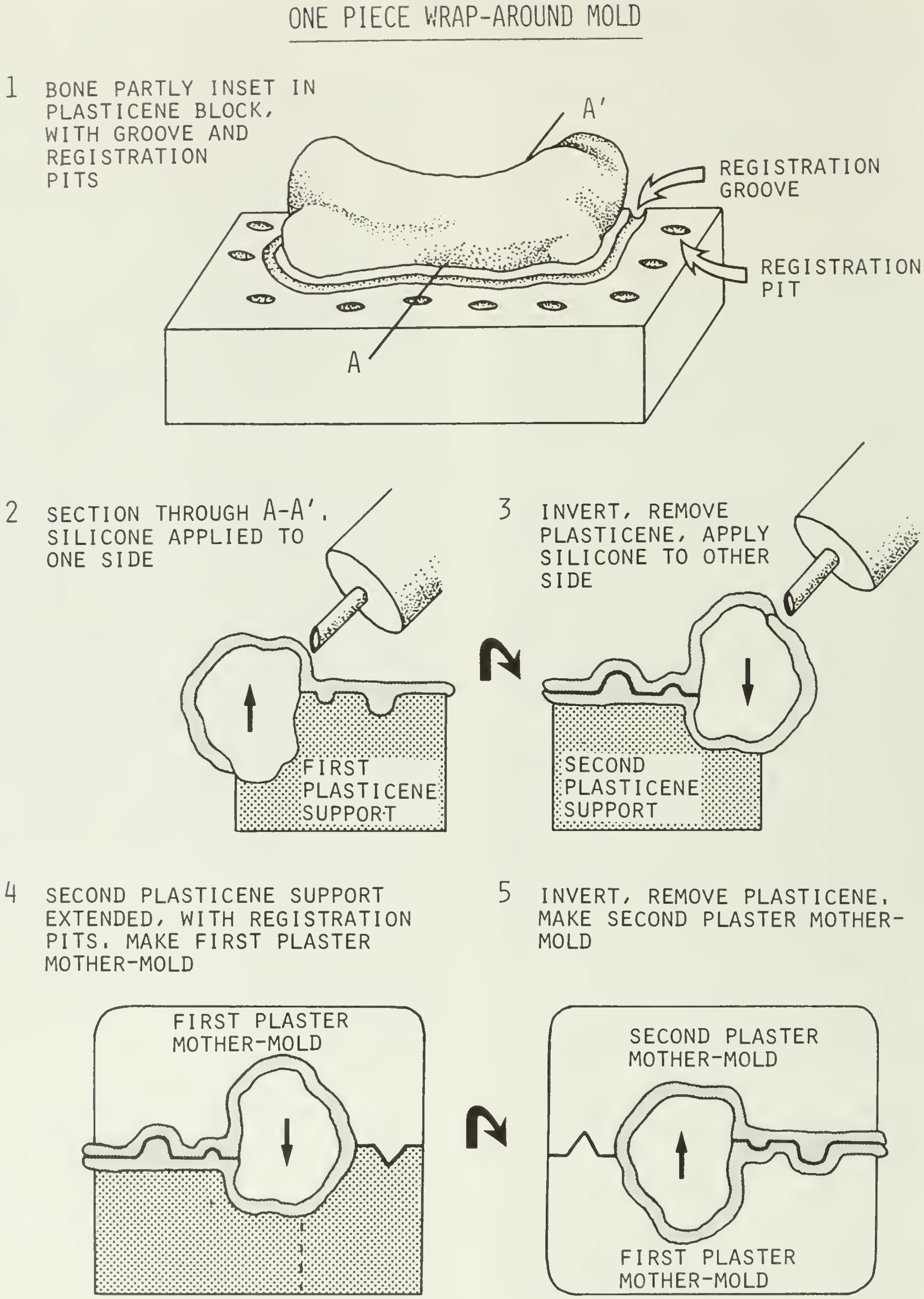
ONE PIECE WRAP-AROUND MOLD
1 BONE PARTLY INSET IN PLASTICENE BLOCK, WITH GROOVE AND REGISTRATION PITS
A'
A
REGISTRATION GROOVE
REGISTRATION PIT
2 SECTION THROUGH A-A'. SILICONE APPLIED TO ONE SIDE
FIRST PLASTICENE SUPPORT
3 INVERT, REMOVE PLASTICENE, APPLY SILICONE TO OTHER SIDE
SECOND PLASTICENE SUPPORT
4 SECOND PLASTICENE SUPPORT EXTENDED, WITH REGISTRATION PITS. MAKE FIRST PLASTER MOTHER-MOLD
FIRST PLASTER MOTHER-MOLD
5 INVERT, REMOVE PLASTICENE. MAKE SECOND PLASTER MOTHER-MOLD
SECOND PLASTER MOTHER-MOLD
FIRST PLASTER MOTHER-MOLD

Fig. 1. Stages in the production of a one piece wrap-around silicone mold.

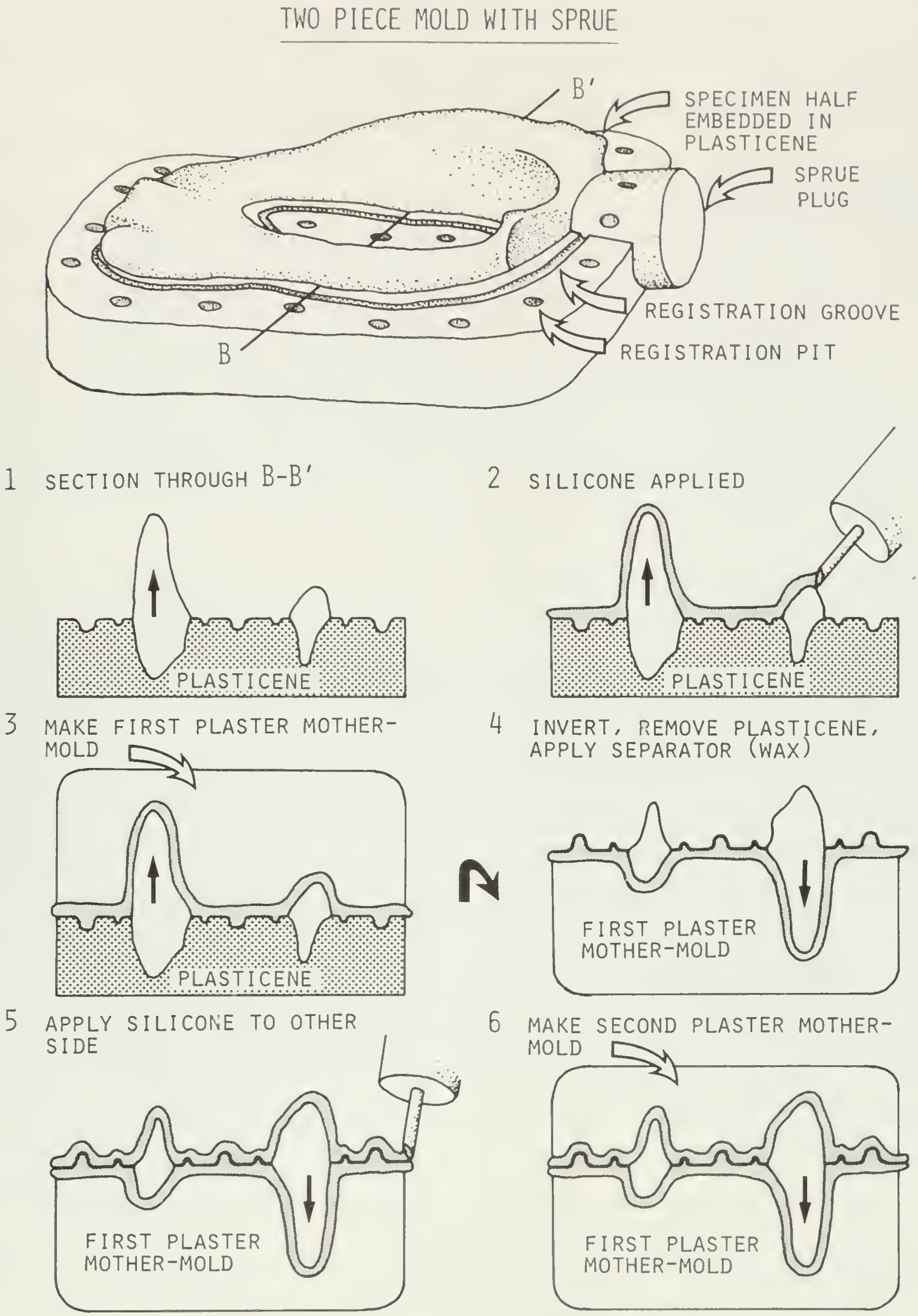
TWO PIECE MOLD WITH SPRUE
B'
SPECIMEN HALF EMBEDDED IN PLASTICENE
SPRUE PLUG
REGISTRATION GROOVE
REGISTRATION PIT
B
1 SECTION THROUGH B-B'
PLASTICENE
2 SILICONE APPLIED
PLASTICENE
3 MAKE FIRST PLASTER MOTHER-MOLD
PLASTICENE
4 INVERT, REMOVE PLASTICENE, APPLY SEPARATOR (WAX)
FIRST PLASTER MOTHER-MOLD
5 APPLY SILICONE TO OTHER SIDE
FIRST PLASTER MOTHER-MOLD
6 MAKE SECOND PLASTER MOTHER-MOLD
FIRST PLASTER MOTHER-MOLD

Fig. 2. Stages in the production of a two piece silicone mold.

Suppliers

Klean Klay #20, neutral.
Art Chemical Products, P.O. Box 678, Huntington, IN 46750, U.S.A.

Dow Corning Silastic RTV 737 Silicone Adhesive/Sealant.
Andrew Gilchrist Inc., 251 Carrier Drive, Rexdale, Ontario, Canada M9W 5Y8.

General Electric Silicone II Sealant.
Silchem Inc., 526 Gordon Baker Rd., Willowdale, Ontario, Canada M2H 3B4.

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PREPARATION AND PRESERVATION OF BURGESS SHALE FOSSILS: OLD MISCONCEPTIONS AND NEW TECHNIQUES

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ABSTRACT—Fossils of soft-bodied and lightly sclerotized organisms from the Middle Cambrian Burgess shale are preserved as thin calcium aluminosilicate films in a rock matrix of similar composition. Orientation of the fossils, relative to roughly horizontal bedding surfaces, is extremely variable. Parts and counterparts do not represent mirror images of bedding plane compressions, but in fact contain different parts of the same organism exposed on a series of minutely different levels. By taking advantage of these properties it is possible to prepare Burgess shale material in a manner similar to that of biological dissection; various photographic techniques then allow selective enhancement of structures revealed in preparation. The generally stable nature of the fossils makes long-term preservation a relatively simple procedure involving, for the most part, provision of proper storage conditions.

PYRITE DISEASE: CASE STUDIES FROM THE REDPATH MUSEUM

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ABSTRACT—Pyrite disease was first noticed at the Redpath Museum in 1951 when the paleontological value of graptolite-bearing shales was completely lost by the decomposition of the iron-bearing sediments to a crumbling white dust. Investigation and treatment of affected mineral and fossil specimens was initiated in 1983. Since then 55 specimens have been treated by neutralization of acidic decomposition products using two specific methods. The preferred treatment involved enclosing the specimen with ammonia vapours (10% ammonium hydroxide in polyethylene glycol 400 to keep the relative humidity low) to neutralize the acidic decomposition products of the pyrite. An alternative method involved immersing the affected specimen in a dilute solution of mono-ethanolamine thioglycollate to neutralize the acid and chelate the iron. In general, the rescue of mineral and fossil specimens suffering from pyrite disease should be approached as an environmental problem. Specimens require storage in areas where 55% rh is not exceeded.

Introduction

Since 1983 the Paleontology and Mineralogy divisions at the Redpath Museum, McGill University, have treated a total of 55 specimens for pyrite disease. The two treatment methods employed are detailed here. Both involve the neutralization of acidic iron sulphates to arrest decomposition of the specimen.

Pyrite disease was first discovered in the Paleontology division of the Redpath Museum in the early 1950s. Fifty pounds of Utica shale (Ordovician) containing graptolite fossils had been collected along the south bank of the Becancour River, Quebec, and stored for the winter. Within a few months of exposure to the normal dampness of the atmosphere in the museum basement (no rh records were kept during this period), the formation and growth of melanterite crystals resulted in the rock splitting into thin laminae, in many cases a fraction of a millimetre thick (Fig. 1). When handled, the laminated product crumbled to powder, and, of course, the paleontological value of the rocks was destroyed (Clark, 1951).

Pyrite disease has long been a problem in the conservation of fossils, and though there is still no preventative treatment which can be said to be absolutely effective, there are several procedures which will arrest the progress of decomposition for several years (Rixon, 1976). Fossils containing pyrite are abundant in sediments formed in reducing environments. Pyrite in sediments occurs in two characteristic forms. Compact crystalline varieties (stable types) are fairly resistant to oxidation in air. Microcrystalline and framboidal varieties (reactive or unstable types) are extremely susceptible to deterioration especially when exposed to air at relative humidity above 55% (Howie, 1979a, 1979b). Specimens containing only compact pyrite show little tendency to absorb moisture or oxidize, even at high rh.

The principal products of oxidation are sulphuric acid and various hydrated iron sulphates. The free acid reacts with and destroys any fossil material composed of calcium carbonate. It is likely that both electrochemical and chemical corrosion models act together in the oxidation process (Howie, 1979b; this volume). Bacterial activity has been suggested as a possible mechanism of oxidation (Radley, 1929; Booth and Sefton, 1970). Howie (1977, 1979b) considered that the evidence for bacterial complicity in the oxidation of pyrite in museum collections was poor.

How to Recognize Pyrite Disease

The presence of white and yellowish-green efflorescent patches on a specimen is often an indication of the onset of pyrite disease; an acidic reaction with pH indicator paper wetted and applied to the efflorescence will confirm this diagnosis. Under a hand lens or binocular microscope three different phases of oxidation are often visible and indicate different degrees of decomposition:

1) Fresh glistening green crystalline masses indicate that pyrite breakdown is active.

2) White efflorescence resembling cigarette ash indicates that oxidation has been arrested at some time but can recur (Fig. 2).

3) Brown iron oxide stains indicate that oxidation has been arrested, either chemically in the past or by

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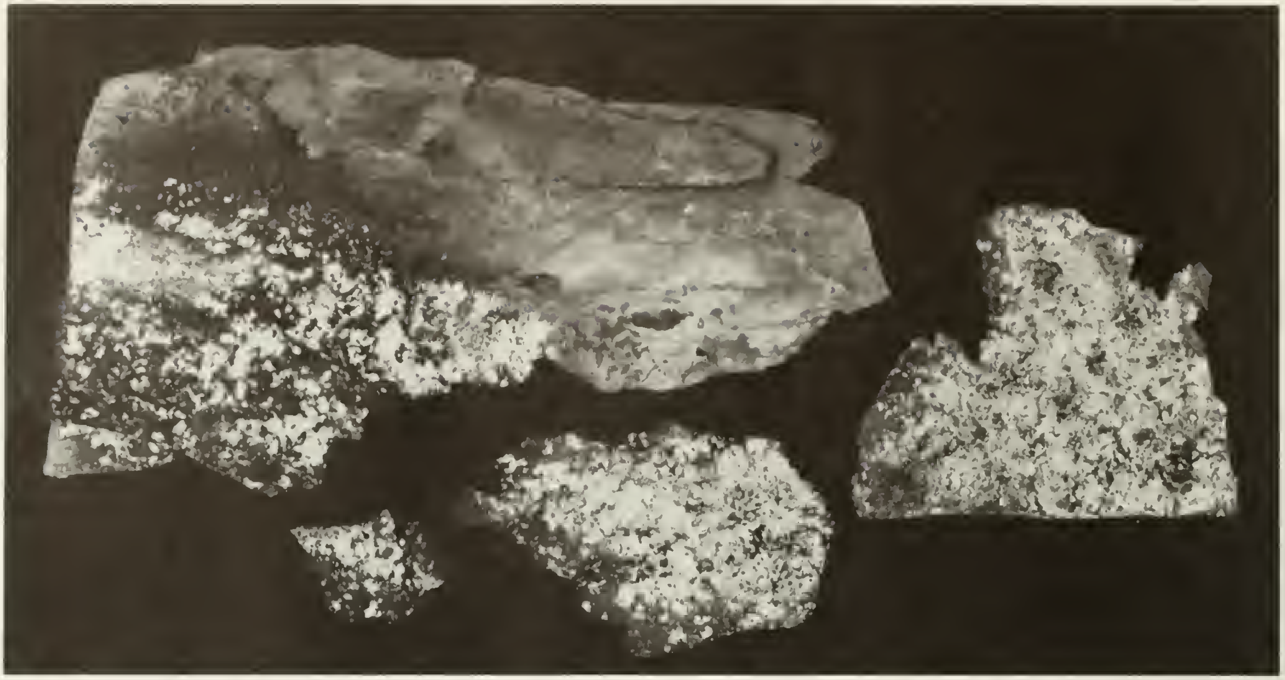

Fig. 1. Utica shale from the Becancour River, Quebec. Specimen has split into thin sheets and shows the formation of melanterite crystals between the layers. Redpath Museum, McGill University. (× 1)

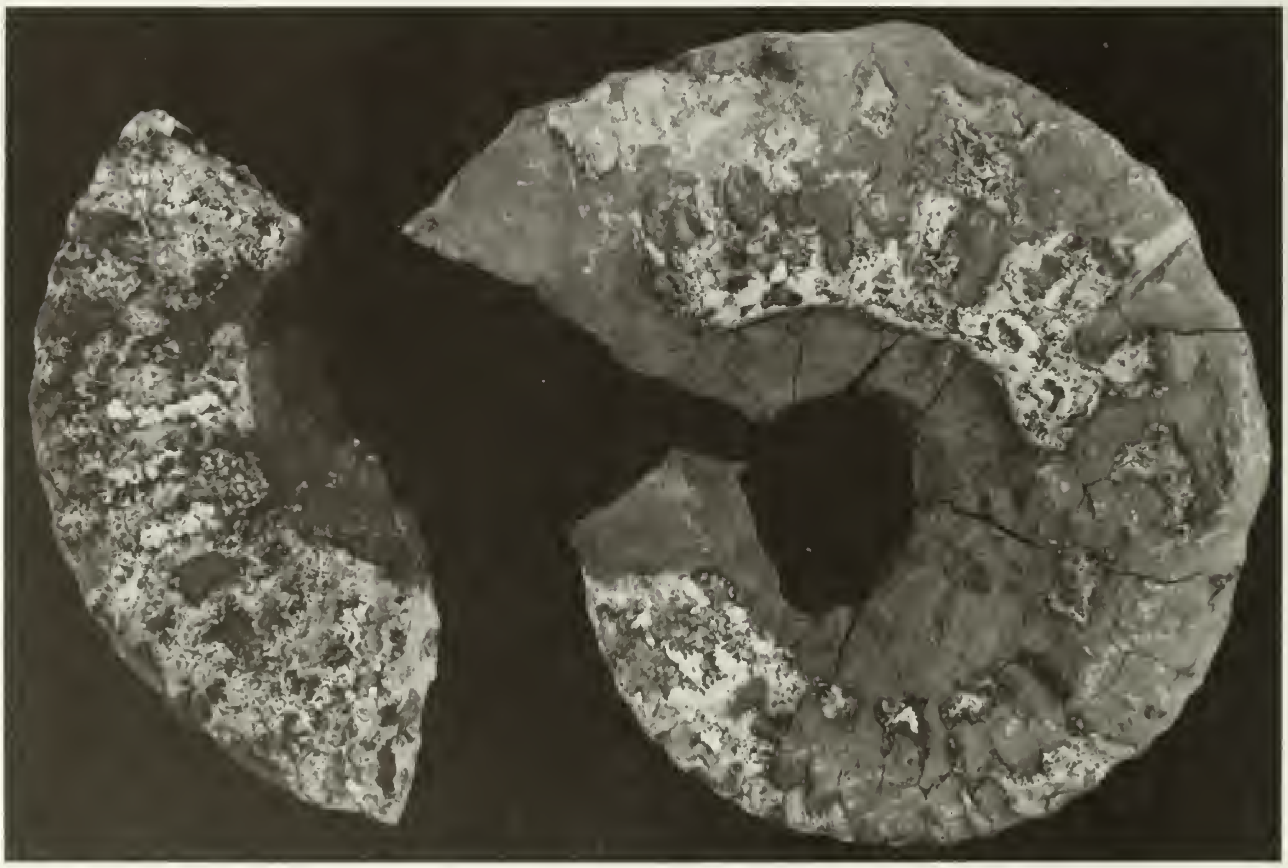

Fig. 2. Unidentified coiled cephalopods showing distinct white, "ash-like" type of crystalline growths. Redpath Museum, McGill University. (× 1)

environmental conditions to which the specimen has been exposed (Howie, 1979a, 1979b).

Treatment

First, the specimen must be transferred immediately to a dry storage or treatment area. Second, the oxidation products must be removed. As the specimen is drying, its appearance may seem to worsen. This is caused by partial dehydration of some of the iron sulphates—a part of the process of arresting the decay (Howie, pers. comm., 1983). The loose breakdown products can be removed by gentle brushing or scraping. Third, the sulphuric acid must be neutralized; this can be done by exposing the specimen to ammonia gas for an undetermined period (at least two weeks, most likely longer). The exposure period depends on the degree to which the specimen is affected and on the size and complexity of the specimen. Polyethylene glycol (PEG) 400 is mixed into a solution of ammonium hydroxide to lower the rh to approximately 30% (R. Waller, pers. comm., 1983). For example, to treat a small ammonite (approximately 6 cm in diameter and 1 cm thick) a 10% solution (volume to weight) of ammonium hydroxide in PEG 400 (20 ml to 200 gm respectively) is prepared in a plastic or glass container inside a fume hood. A plastic-coated metal rack is placed over the ammonium solution and the ammonite is set on the rack. A polyethylene tent covers the treatment unit to concentrate the ammonium vapours and the entire structure is placed into the fume hood (Fig. 3).

An alternative treatment method (Howie, pers. comm., 1983), which eliminates the ammonia neutralization stage, employs a solution of ethanolamine thioglycollate. This reagent, in dilute solution in alcohol, will both neutralize the acid and remove the iron products in one stage. The amine neutralizes the acid while the thiol compound chelates the iron liberated by the oxidized pyrite and renders it soluble as a red-coloured complex (rust). The use of this substance is discussed in detail by Cornish and Doyle (1984).

Discussion

FOSSILS

In 1983 a swollen and cracked specimen of *Ammonites margitatus* var. *gigas* (Jurassic, Reutlingen, Germany) was removed from storage at the Redpath Museum and treated with ethanolamine thioglycollate. The specimen was immersed for three days in a closed container in a fume hood. The solution was changed as it became oxidized by air to a brown insoluble precipitate. After treatment the specimen was washed in clean alcohol and dried. The specimen is now stored in a metal cabinet in a drier area of the museum where rh does not exceed 50%. It has shown no further indication of decomposition.

In the summer of 1983, approximately 50 specimens of early amphibians from the Nyrany coal shales, Czechoslovakia (Upper Carboniferous) were treated by ammonia neutralization. Because of lack of time, the material was not exposed to ammonia vapours long enough and it was thought that the neutralization phase was not completed (Fig. 4). Baskets containing silica gel were fitted inside the storage drawers to maintain a low rh. The drawers were not monitored, but the gel was changed at approximately two-month intervals as it became saturated. Upon re-examination in 1985 approximately 10% of the specimens were again suffering from decomposition and were removed for conservation. Before treatment in 1983 these particular specimens were the most seriously diseased. The pyrite in the matrix had oxidized causing local swelling, delamination, and cracking where migrating oxidation products had crystallized in cleavages (Fig. 5). The specimens had not been coated with an organic consolidant.

A coniferous log from the Cretaceous of Lebanon was treated by ammonia neutralization. However, because of an interpretive error by the technician, the ammonium solution was composed of 10% PEG in ammonium hydroxide (20 gm in 200 ml respectively)—completely the opposite of the recommended treatment procedure. This error could have caused extreme damage to the specimen due to condensation in the fissures, but it is assumed that the loose polyethylene tent covering the specimen allowed most of the water vapour to escape. Before treatment, characteristic white, ashlike products of decomposition surfaced through the bark and large cracks and fractures appeared indiscriminately (Fig. 6A). In several areas, fresh glistening masses indicated that pyrite breakdown was active and in other areas brown oxide stains showed that oxidation had been chemically neutralized. After treatment the white and yellowish patches changed to rust coloured stains. The cracks remained (Fig. 6B). A consolidant of polyvinyl acetate (PVA) in toluene was applied to penetrate and bind the friable areas together.

MINERALS

Pyrite and marcasite form part of most mineral collections. At the Redpath Museum these minerals represent approximately 20% of the total collection; of this approximately 60 to 70% show evidence of pyrite disease (Fig. 7). The nature of the decomposition ranges from minor to extreme; in some cases the specimen has been completely destroyed. The problem was first noticed in early 1981. The main indicator was the friability and lacklustre nature of the specimens, as well as the presence of fresh, green crystalline masses. Three pyrite and marcasite specimens have been treated using ammonium hydroxide neutralization.

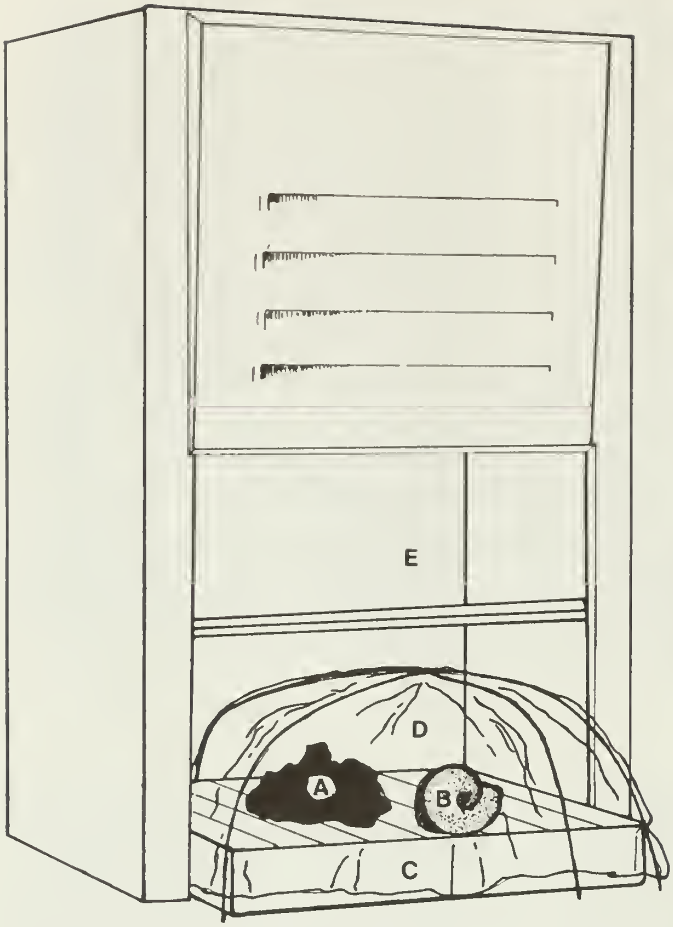

Fig. 3. Neutralization of specimens for pyrite disease. Affected specimens (A and B) are suspended over a solution of 10% ammonium hydroxide in PEG (C). Treatment unit is covered with tent of polyethylene sheeting (D) to concentrate vapours. This is placed in a fume hood (E) for duration of exposure.

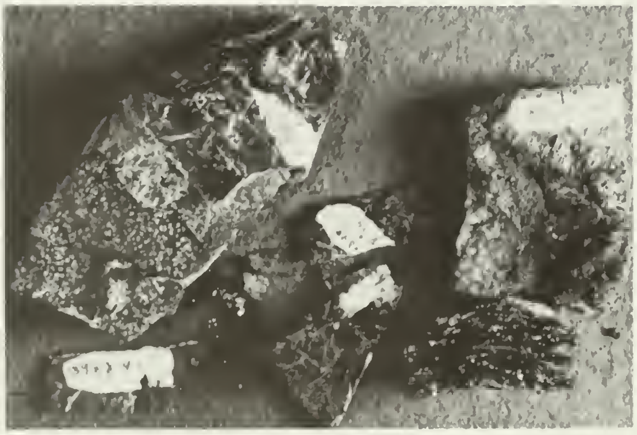

Fig. 5. *Solenodonsaurus* sp. 1898/x, 44
Seriously decomposing specimen. Pyrite in matrix has caused delamination and breakage to specimen. (× 0.7)

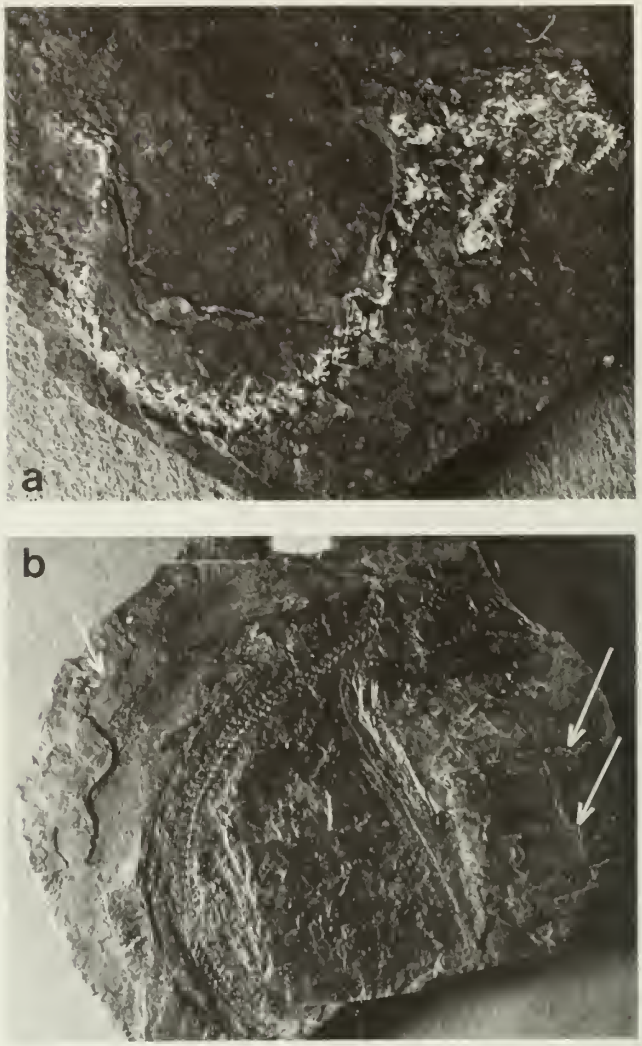

Fig. 4.

A. *Microbrachis pelikani* Fritsch 1898/x, 39
Before treatment for pyrite disease. White, "ash-like" growths cover fossilized skeleton. Skull is at upper right. In Paleont./Geol. Abtlg., Naturhistorisches Museum, Vienna. (× 1.8)

B. *Sauropleura scalaris* (Fritsch) 1898/32/11
After treatment. Skeleton has been etched with dilute HC1 and then the entire specimen has been exposed to ammonium vapours. Arrow indicates faint trace of white crystal growth in cleavage cracks of the coal. (× 0.7)

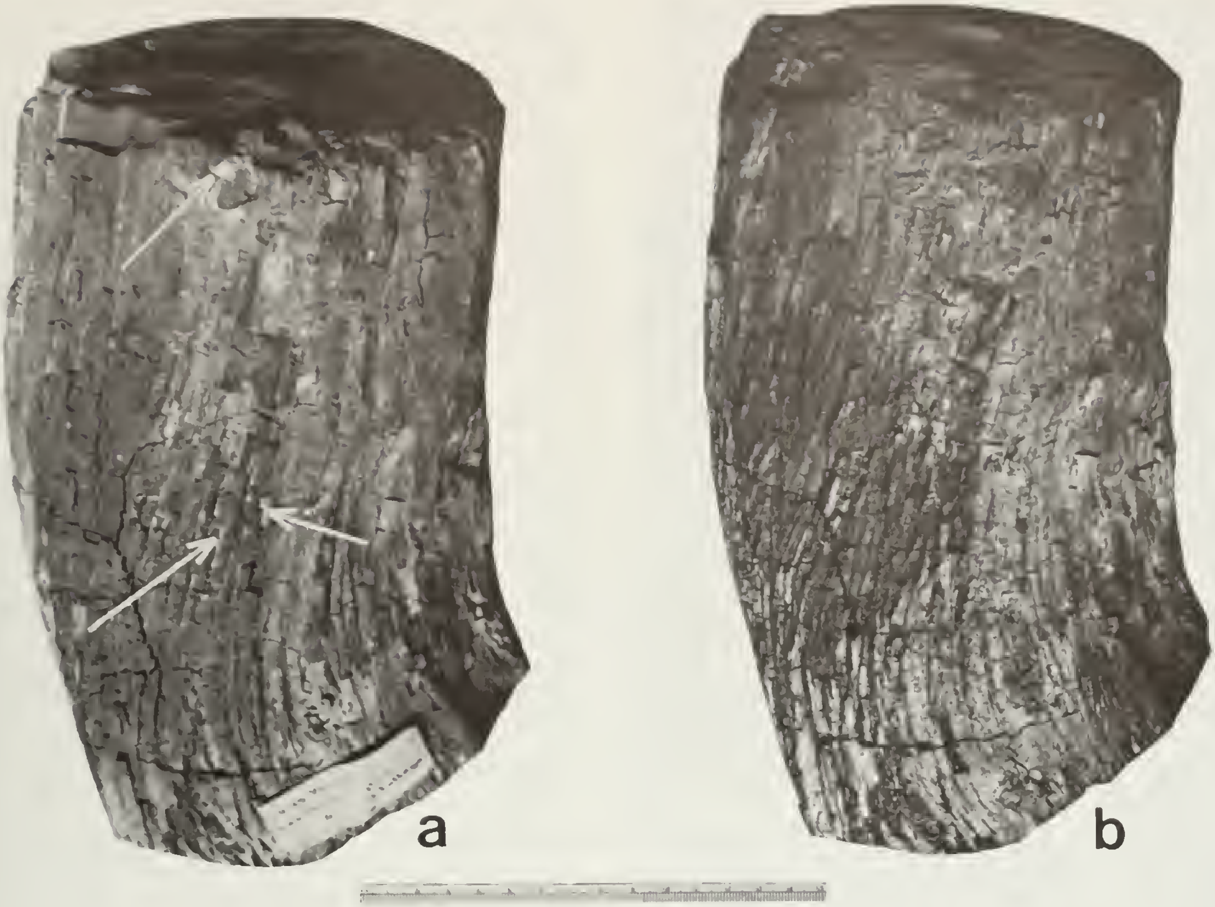

Fig. 6. Unidentified coniferous log, Cretaceous, Lebanon, RM 7102. Scale bar = 15 cm.

A. Before treatment. Arrows indicate deposits of breakdown products of pyrite disease.

B. After treatment. Log shows stabilized condition after neutralization. Large, indiscriminate cracks remain.

The first pyrite specimen treated in 1983 was from Guanajuato, Mexico. The specimen had pockets of green efflorescence, was dull in appearance, and was extremely friable. The display area surrounding the specimen was covered by small pieces that had flaked off. The pyrite specimen underwent two separate treatment periods. After a period of five weeks of ammonium neutralization and an observation period of three months, white, ashlike products of decomposition were still visible. Following a second exposure to ammonia for a period of six weeks the decomposition seemed to have been arrested; the specimen was now covered with red hydrated oxides.

A specimen of marcasite and sphalerite on galena from Sayerville, New Jersey, was also treated. As with the pyrite specimen, the marcasite had suffered extensive damage. Large pieces had become separated from the specimen and during moving it suffered further, and perhaps irreparable damage. Two separate ammonium neutralization treatment periods were used, for a total of 11 weeks. In the case of this specimen, even after 11 weeks of treatment, the white efflorescence resembling cigarette ash and the green crystalline masses were still visible.

The third specimen treated was a pyrite specimen from Rio Marina, Elba. The surface of this specimen was shiny and casual examination revealed no evidence of pyrite oxidation. The specimen had been displayed resting on absorbent cotton, and when it was moved, brown acid stains were noticed on the cotton. The specimen was re-examined using a hand lens, and small pockets of fresh efflorescence were found. Three weeks of ammonium neutralization were sufficient to treat the specimen. Because the problem was minor, and was treated immediately, this specimen had not decomposed as severely as the two previously mentioned.

In contrast to the fossil specimens none of the mineral specimens have been consolidated. This was partly due to the fact that decomposition may not have been completely arrested. Moreover, when allowed to dry in air, the consolidant often imparts a high gloss to specimens which

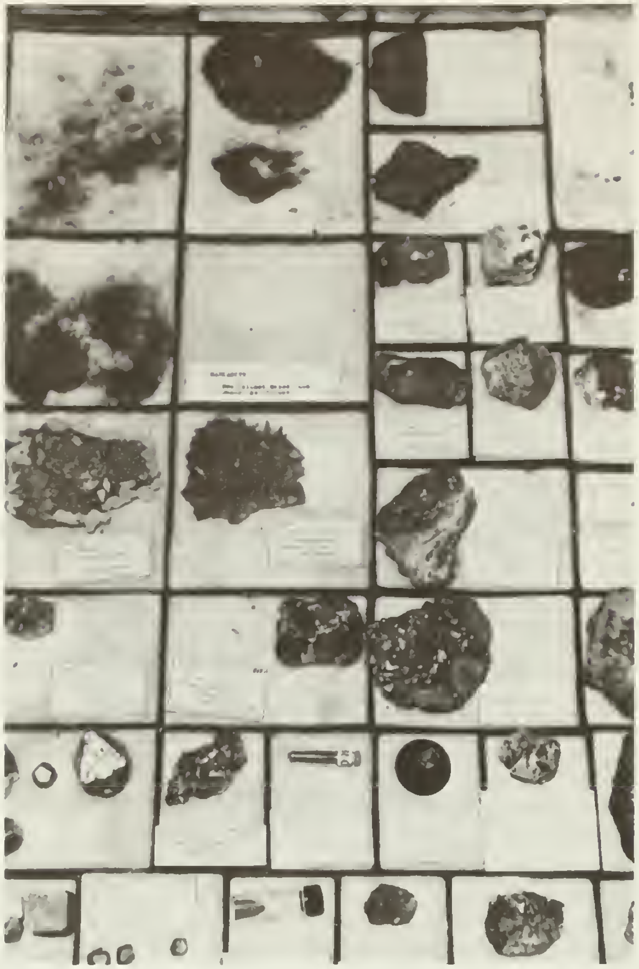

Fig. 7. Pyrite and marcasite mineral cases showing some of the warning signs of pyrite disease. Note the acid burns on the absorbent cotton. (× 0.25)

is sometimes unacceptable, that is, a false lustre to pyrite and marcasite specimens. The specimens will be observed for a period of time to see if decomposition has been arrested before consolidation is attempted.

Conclusion

In terms of general collection management, the rescue of fossil and mineral specimens suffering from pyrite oxidation should be approached initially as an environmental problem. Pyrite and marcasite specimens, whether treated or not, require storage in areas where, ideally, 55% rh is not exceeded. Continuous monitoring of the storage environment will give early warning of expected problems, allowing steps to be taken to reduce the rh before serious damage occurs. When affected material is found it should be transferred immediately to dry storage or treatment areas. Small specimens can be dried satisfactorily by dessication over silica gel and then treated, that is, oxidation products removed, sulphuric acid neutralized and consolidated or restored as per Rixon (1976) and Howie (1977).

During ammonium treatment of affected mineral specimens, several observations were made. The structural and physical characteristics of the specimens may influence the degree of decomposition that they suffer. In the mineral collection of the Redpath Museum it seems that the larger the crystal size and the simpler the mineral structure, the less likely it is that decomposition will start. One reason may be that with smaller and more complex crystals there is more surface area available to attack.

Neutralization of acidic decomposition products does not guarantee complete arrest of the breakdown of iron-bearing fossils or minerals. At the Redpath Museum we have treated all but one specimen by exposure to ammonia vapour where PEG was added to reduce rh. After treatment recurrence of decomposition has been observed in five of the fossils, which were initially badly decomposing, and two of the mineral specimens. This may be due to the fact that the museum's temperature and humidity levels fluctuate constantly, with little hope of being controlled. Only one fossil was treated using ethanolamine thioglycollate because the fumes were considered to be too dangerous to be contained safely in our homemade fume hood (from the Merck Chemical Index [Rahway, 1976]: ethanolamine, $HOCH_2CH_2NH_2$—highly toxic; strong irritant; tolerance 3 ppm in air). However, Cornish and Doyle (1984) describe ethanolamine thioglycollate as a substance of "comparatively low toxicity" and "safer to use than any previous techniques"

The treatments described here are not necessarily recipes for success. Our case studies were implemented in order to examine the effects of specific treatments and to monitor and observe the specimens before and after these treatments. Neither of the authors has a background in chemistry and we do not have the definitive explanation for treatment of decomposition of iron pyrites. In fact, our informal experimentation with treatment methods and recipes allowed for interpretive error with one specimen that could have caused serious damage. The authors of this paper caution any workers in the field to obtain advice from a chemical conservator, an occupational hygienist, or safety officer before initiating projects with unfamiliar chemicals or mixtures of chemicals.

In conclusion, there is still a great deal to be learned about the treatment of pyrite disease and perhaps more importantly, about its prevention. The historical literature on the decomposition of iron pyrites encourages removal or neutralization of the acidic alteration products of pyrite decomposition. However, this procedure has never been verified as necessary or effective.

Acknowledgements

We would like to thank K. Zahn for guiding us carefully through chemical conservation procedures. Special thanks to Frank Howie for clear letters of advice and to Robert Waller for his keen interest and assistance with our experiments. We are indebted to David Singleton, Helen Kaylor, Susan Gabe, Sylvia Adams, Jeffrey Fourestier, and Barbara Lawson, who contributed in many ways to the success of the project. We are grateful to Dr. Robert Carroll, director of the Redpath Museum, for encouraging our experimentation and supporting our research endeavours.

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AN ELECTROCHEMICAL MECHANISM FOR THE OXIDATION OF PYRITE IN MUSEUM-STORED SPECIMENS

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ABSTRACT—The oxidation of fine-grained pyrite under simulated museum conditions of elevated relative humidity has been followed by oxygen-18 tracer tests. The oxidation has been found to proceed via a series of electrochemical mechanisms whereby the sulphate ions formed obtained their oxygen from the water vapour phase rather than from atmospheric oxygen.

The probable anodic dissolution reaction is:

$FeS_2 + 8H_2O \rightarrow FeSO_4 + H_2SO_4 + 14H^+ + 14e$

The cathodic reaction is:

$O_2 + 4H^+ + 4e \rightarrow 2H_2O$

The fate of the cathodically formed water is largely as hydrate water of crystallization. Side reactions involving the oxidation of ferrous to ferric ions and reduction or electrochemical dissolution of sulphide to sulphur are not significant during the initial stages of oxidation.

The detection of a range of hydrated ferrous sulphates (e.g., szomolnokite, $FeSO_4 \cdot H_2O$ and melanterite, $FeSO_4 \cdot 7H_2O$) at the earliest observable stages of oxidation is in accordance with a water vapour pressure, rather than oxygen diffusion, controlled causation for pyrite oxidation.

PYRITE DISEASE: CAUSE AND TREATMENT

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ABSTRACT—Pyrite disease is the common term for the oxidation of pyrite. This occurs when a susceptible form of the mineral is exposed to atmospheric oxygen and moisture. The reaction is complex, but the major products are hydrated ferrous sulphate and sulphuric acid.

The reaction is electrochemical and the sulphuric acid produced is an excellent electrolyte at all levels of relative humidity. These facts suggest that the complete removal of sulphuric acid or its complete conversion to a non-deliquescent substance is an essential step in any stabilization treatment.

Numerous solutions, both aqueous and non-aqueous, have been recommended for the neutralization and removal of sulphuric acid from affected specimens. These solutions can be effective for treating specimens that have not extensively deteriorated. Unfortunately, most deteriorated specimens disintegrate when placed in a fluid. Therefore, treatments that employ gases to convert the sulphuric acid to more humidity-stable compounds are required.

Dry ammonia gas is effective, but the equipment required for its safe use is not commonly available. The vapour from a simple ammonium hydroxide solution cannot be used since it condenses in fractures causing specimen disintegration. The addition of hygroscopic chemicals such as glycols to solutions of ammonium hydroxide will depress the vapour concentration and prevent condensation within fractures. Progress in developing a treatment scheme employing such solutions will be reported.

A METHOD FOR CLEARING AND STAINING SMALL FISHES, AMPHIBIANS, AND REPTILES

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ABSTRACT—The enyzme process of clearing and staining small ectothermic vertebrates is reviewed. A modified version of Taylor's method is discussed. This involves clearing muscle tissue with the proteolytic enzyme, trypsin, and double staining: cartilage with Alcian Blue, and bone with Alizarin Red S. The emphasis is on a description of the process, and discussion of problems and possible solutions.

Introduction

The clearing and staining process has become an invaluable tool for the study of skeletons of small vertebrate animals, especially fishes, amphibians, and reptiles.

As fish skeletons are not weight bearing, the component elements are less robust than those of tetrapods, and they are more numerous. As a result, when the muscle tissue is removed, the fish skeleton tends to distort or fall apart. Hence the standard ways of preparing a dried tetrapod skeleton are not as effective for fishes. X-rays, also used for skeletal examination, suffer from being merely two-dimensional projections, so information is lost.

Clearing and staining is a superior technique for small fishes because the skeletons remain intact with minimal distortion. Unlike an X-ray, the specimen may be dissected to determine the relationships among the bones. In addition, the differential staining increases the visibility of different skeletal tissues. The process usually involves the maceration or digestion of muscular tissue to render it transparent. Alcian Blue is used to stain acid mucopolysaccharides found in cartilage. Alizarin Red is used to stain calcified tissues such as bones and fin rays.

What follows is an adaptation of the method introduced by Taylor (1967). Being an adaptation, it is far from original. However, through my experiences, both in the lab and the library, I have encountered a number of problems and discovered some possible solutions. I have also developed some modifications which may prove useful. I have included some suggestions for further experimentation. This process is far from precise, and at times, resembles art more than science. I therefore felt that I should share with others my trials and tribulations in the hope that it may make their work a little easier.

Materials and Methods

MATERIALS

distilled water
65–70% ethyl alcohol (EtOH)
95% ethyl alcohol (EtOH)
glacial acetic acid
Alcian Blue 8GX, 8GN, 8GS, or equivalent, powder
potassium hydroxide (KOH) or sodium hydroxide (NaOH), U.S.P.
hydrogen peroxide (H_2O_2), 3% solution, laboratory grade
borax powder (sodium tetraborate), ($Na_2B_4O_7 \cdot 10H_2O$) A.C.S.
trypsin powder, purified
Alizarin Red S powder, certified by B.S.C.
glycerin, U.S.P.
thymol N.F. crystals ($C_{10}H_{14}O$); can also use phenol

METHODS

Preparation of Solutions

1) Alcian Blue stain solution. Prepare a solution of four parts glacial acetic acid and six parts 95% ethyl alcohol (add acid to alcohol). Add small amounts of Alcian Blue powder until the solution becomes deep blue, but not so dark that it becomes impossible to see fish in the stain solution. For 1600 ml of solution, combine 640 ml of glacial acetic acid, 960 ml of 95% ethyl alcohol, and 0.25 g Alcian Blue powder (0.25 g approximately = ¼ tsp; 1 ml approximately = 0.40 g). Up to 0.50 g may be used for darker stain.

2) KOH (or NaOH) solution. Prepare a stock solution of ½ to 1% hydroxide in distilled water.

3) Saturated borax solution. Add excess sodium borate powder to four or more litres of distilled water. Mix and then allow excess powder to settle. It is best to have one container with the excess borax powder; pour off the supernatant into a separate container for working solution and then add more distilled water to the borax in the first container.

4) Borax-buffer solution. Prepare a solution of three parts saturated borax and seven parts distilled water. This solution can be used as a rinse and for the enzyme-buffer solution. Each lot of fish (no more than five specimens in a

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lot) will require approximately 200 ml of solution. For 200 ml of buffer, use 60 ml of saturated borax solution and 140 ml of distilled water; for 250 ml, use 75 ml of saturated borax and 175 ml of distilled water; and for 300 ml, use 90 ml of saturated borax and 210 ml of water.

5) Glycerin solutions. Mix the following solutions of glycerin and 65% EtOH (stock hydroxide or distilled water may also be used instead of 65% EtOH).

40%—four parts glycerin and six parts alcohol (or four parts 70% glycerin and three parts alcohol)

70%—seven parts glycerin and three parts alcohol

6) Alcohol-hydroxide solution. This solution is principally for the Alizarin Red S stain; however, it can also be used as a rinse. A small amount of the stock hydroxide is added to 65–70% ethyl alcohol. For 1600 ml of solution, add 100 ml of stock hydroxide solution to 1500 ml of 65–70% ethly alcohol. For the red stain, add 0.25 g of Alizarin Red S powder (¼ tsp approximately equals 0.5 g; 1 ml approximately equals 0.9 g). The solution should be a deep purple colour.

CLEAR AND STAIN METHOD

This assumes that specimens have been fixed in formalin and stored in alcohol. Fresh specimens should be fixed in 10% formalin and rinsed in 65% ethyl alcohol (not water). It is usually not necessary to skin fishes or amphibians unless the skin is particularly thick. However reptile skins are impervious to the solutions, so these animals must first be skinned.

A. Staining with Alcian Blue—Place specimens in 95% ethyl alcohol for 24 hours and then change to fresh alcohol for an additional 24 hours to dehydrate specimens. Transfer specimens into stock Alcian Blue stain solution. The time in Alcian Blue solution should be as short as possible but will depend upon the size of the specimens, their condition prior to staining, and the intensity of the stain solution. Generally it takes from 8 to 24 hours. Small fishes such as gobies are adequately stained after 3 or 4 hours. The ability to determine if specimens are adequately stained improves with experience. Place stained specimens in stock saturated borax for approximately 24 hours to neutralize the acid. If a strong acetic acid smell remains, then place in a fresh stock borax solution for an additional 24 hours (the solution may have to be changed several times).

B. Bleaching the Specimens—Bleach specimens in 3% hydrogen peroxide until all pigmented areas become decidely pale. This usually takes from 8 to 24 hours. The peroxide may be diluted with stock hydroxide (or saturated borax or distilled water) if so desired. Fishes with little pigment need not be bleached. The pigment is not completely removed in the bleach solution. However, both the pigment and the excess blue stain usually disappear in the enzyme-buffer solution. After bleaching, the specimens are placed in stock borax solution for 12 to 24 hours to neutralize the bleach. Specimens that prove hard to bleach may be placed under a light (UV or fluorescent); however, this usually is not necessary. Specimens that prove hard to clear may be left in peroxide/hydroxide solution for a prolonged period (CAUTION: this solution is very harsh and may destroy delicate specimens). This facilitates enyzme clearing.

C. Clearing the Specimens—Prepare the enzyme-buffer solution immediately prior to use. For each lot of specimens, mix ½ to 1 ml of trypsin powder into 200 ml of borax buffer solution. Place the specimens into this solution. For a larger volume of specimens increase both the amount of borax buffer solution and trypsin powder. After two or three days the solution will become decidedly blue from Alcian Blue stain and pigment leaching out of the specimens. The enzyme-buffer solution should therefore be changed at that time. Thereafter, the specimens may be left in the enzyme-buffer for up to two weeks before it is changed. Ideally the solution should be changed once a week until specimens become transparent (or translucent if they are large). *The specimens are very fragile now.*

In order not to contaminate the Alizarin Red S solution, the specimens should be rinsed. Larger, less fragile specimens may be placed in a rinse of 65% EtOH (or saturated borax or distilled water). However, smaller specimens should be taken through a series of dilutions of the alcohol-hydroxide solution before they are placed in the red stain.

Place the specimens in borax-buffer solution for half an hour. Then place them for half an hour in each of the following solutions: a) one part alcohol-hydroxide solution to three parts distilled water; b) one part alcohol-hydroxide solution to one part distilled water; c) three parts alcohol-hydroxide solution to one part distilled water. Save these solutions for rinsing after the staining procedure.

D. Staining with Alizarin Red S—Place the specimens in the Alizarin Red S solution for 8 to 24 hours. All calcified tissues, including fin rays and scales, should be stained dark red. Rinsing will remove the excess stain.

Rinse the specimens in the solutions saved from before the staining. Be sure to reverse the order of the dilutions.

E. Final Preparation of the Specimens—It is often difficult to render specimens transparent by enzyme digestion alone (especially the larger ones). The optical density of the remaining muscle tissue is very close to that of glycerin. Therefore the visibility of the skeletal structures is improved by storing the specimens in glycerin. Moreover the viscosity of the glycerin supports the fragile skeletons.

The specimens are worked through a series of glycerin solutions: a) 24 to 48 hours in 40% glycerin; b) 24 to 48 hours in 70% glycerin; c) 24 to 48 hours in 100% glycerin. The specimens are then stored in 100% glycerin with a few crystals of thymol to inhibit fungal growth.

Discussion

It cannot be overemphasized that as the specimens go through the procedure they become increasingly *fragile*. Therefore the less they are handled, and the shorter the time the procedure takes, the better. Small fishes should be placed in basketlike containers so that they may be moved from solution to solution without being touched by implements which might damage them.

Baskets for holding small specimens can be made from commercial yogurt cups (175 g size). These containers fit neatly into Pyrex #3520 glass dishes (100 mm × 80 mm high), which are useful for clearing and staining small specimens. A hole in the bottom of the cup may be cut out and plastic screening attached. The screening may be melted into the plastic with a soldering iron. Remember to remove all the ink from the cup's surface (with 95% ethyl alcohol).

The times suggested for the various steps are recommendations only (especially for the stain solutions). Specimens generally float when they are first placed in rinse solutions; they may be removed from those solutions when they have sunk.

Rinsing between steps protects solutions from contamination, which is important if the solutions are to be reused. Saturated borax is a good rinse solution since it maintains the pH of the specimens at an ideal level. If the pH is too low, calcium is leached from the bones and the trypsin is denatured. The hydroxide is generally not a good rinse solution since it may cause smaller animals to disarticulate or disintegrate. Ethyl alcohol will denature trypsin but it may be used as a rinse after that step. The alcohol will inhibit microbial growth and seems to produce firmer specimens. Distilled water is the least expensive rinse, but it confers no special advantage.

Simons and Van Horn (1971) felt that fixation in formalin inhibits the clearing of the specimens. It is for this reason that they used acetic acid and 95% ethyl alcohol as a fixative; hence its use as a solvent for the Alcian Blue. We have found no problem with formalin.

Simons and Van Horn (1971) placed specimens in Alcian Blue immediately after acid/alcohol fixation. They then dehydrated the specimens. They felt that the dehydration would result in transparent specimens.

Others (Dingerkus and Uhler, 1977, for example) have adopted Simons and Van Horn's acid/alcohol solvent. They felt that the alcohol would help dehydrate the specimens while the acid would help the Alcian Blue bind to acid mucopolysaccharides in the cartilage. These mucopolysaccharides are water soluble and may be lost if the specimens are washed. For this reason specimens should not be washed after fixation and should be dehydrated before Alcian Blue staining.

Absolute alcohol is sometimes used for dehydration; however, 95% ethyl alcohol appears adequate. Besides it is difficult to keep absolute alcohol "absolute".

Caution should be taken when the specimens are in the Alcian Blue solution. If they are overstained, it is extremely difficult to remove the excess, especially from the skin and muscle. Moreover, the specimens cannot be restained if the original stain is inadequate, as specimens tend to fall apart. It is difficult to tell if specimens are properly stained since much of the stain is removed during the bleaching and digestion processes. It may be a good idea to increase the amount of Alcian Blue powder in the staining solution in order to minimize the time the animals are in it. The longer the specimens are in the acid, the more likely it is that calcium will be leached from the bones.

Care should also be taken with the bleaching process because excessive gas may be released causing tissues, especially eyeballs, to swell. More gas seems to be given off when the H_2O_2 is diluted with hydroxide. However, the bleaching is faster and more complete, probably as a result of the hydroxide breaking down the tissue. If the specimens are not adequately bleached, they can be returned to the solution, unless they have been in the digestion process for a prolonged time. They should be rinsed before being returned to the bleach. Because the bleaching and enzyme solutions help remove excess Alcian Blue, it is useful to put even skinned animals through the bleach.

If the animals are in good condition, the process should be completed with no more than two or three changes of solutions. However, many specimens are not ideal. Animals with complete data are needed for the main alcoholic collection. Many of the specimens available for clearing and staining were collected many years ago and have incomplete data, or are of unknown origin. Their method of preservation and storage may be unknown and may not be ideal for the clearing and staining process.

Sometimes the animals do not digest well in the enzyme. These specimens usually feel stiff when they come out of the dehydration step, and after bleaching they appear a yellowish-brown colour. Frequently these show few signs of digestion even after a few months in the enzyme.

There are a few ways that these specimens might be salvaged. The hardened muscle tissue could be lanced with a dissecting needle. The specimens could be left in any of the following three solutions for a period of time: peroxide/hydroxide, hydroxide, or pancreatin (a powder that contains a variety of enzymes including trypsin). Success is variable with these methods.

These methods work with much greater success on well-preserved large specimens (greater than 100 mm total length), which also clear very slowly. In addition, the skin of heavily muscled fish should be slit before they go through the process.

Another problem is contamination of the enzyme by micro-organisms. This occurs occasionally with larger fish and frequently with reptiles and amphibians, especially snakes and lizards. In these cases, the enzyme solution should be changed more frequently and affected specimens may have to be transferred to ethyl alcohol for up to a week to kill the microbes. The container should be disinfected before reuse. Another reason for slow clearing is inactive trypsin. The trypsin should be refrigerated when not in use. Specimens stored in Ionol do not clear at all.

If the specimens have not stained red enough, they may be worked back to the Alizarin. The time in the Alizarin Red is not as critical as that in the Alcian Blue, since excess Alizarin Red will eventually leach out.

The use of diluted rinse solutions before and after using the Alizarin Red stain is designed to minimize osmotic stress on the specimens, which may result in loss of bony elements. However, this generally is not a problem for larger animals, which may be rinsed in ethyl alcohol.

If after a day in 40% glycerin specimens have not cleared, they should be worked back to the enzyme-buffer solution. They may have to be restained in Alizarin Red S.

Ethyl alcohol, rather than hydroxide, was used to dilute the glycerin because the resulting specimens seemed to be firmer. Taylor (1967) used hydroxide so that his stored specimens would have a slightly higher residual pH. However, we rinse in 100% glycerin before storage, which obviates the use of hydroxide. Furthermore, hydroxide in the storage solution may cause specimens to disintegrate. The use of the 100% glycerin rinse helps to minimize the amount of water in the final storage fluid.

If specimens have to be left between solutions for more than a day, place them in saturated borax or ethyl alcohol (if appropriate). They may be left for a prolonged period in any of the glycerin solutions. If a black or brown residue appears in the glycerin, the cause may be a reaction with a metal lid. Specimens should be stored in plastic or glass only.

The finished product may be photographed using a standard copy set-up, with a light box or table as a background. The effect of the light box is to accent the transparency of the specimens and provide a white, shadowless background. The exposure should be determined with a grey card positioned in place of the specimens. The camera settings are derived from a reading taken from the two reflected lights only, but not the light box. However, exposures should be bracketed, since the variation of the specimens makes the results unpredictable.

Conclusions

This has been a kind of ''cookbook'', and as this implies, the results are not precisely determined and are subject to much variation, especially when the animals used are not in good condition, or are not prepared and preserved with clearing and staining in mind. We have, however, used this method over a number of years and have found it to be a quick and gentle technique. However, the method (as does any recipe) continues to be open to modifications and improvements to the efficiency of the process and the quality of the final product.

The use of acetic acid and ethyl alcohol as the solvent for Alcian Blue seems to have originated with Simons and Van Horn (1971), who used the solution as a fixative for their specimens. This would suggest that the ideal solvent for Alcian Blue should be the liquid in which the specimens are fixed or stored. This would eliminate the extra steps preceding the blue staining. I therefore propose that various solvents for Alcian Blue should be examined. The most logical would be 65 to 70% ethyl alcohol for those specimens stored in that liquid and 10% formalin for fresh specimens that are destined for clearing and staining. Perhaps the specimens could even be immediately fixed in a solution of Alcian Blue in 10% formalin. The fewer the steps, the less stress the specimens endure, and the better the results.

Acknowledgements

I would like to thank those members of the Department of Ichthyology and Herpetology, Royal Ontario Museum, who have contributed to the development of this procedure over the years. The most notable are Jill Stephens, Alan Emery, and Cheryl Goodchild.

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NERVE STAINING USING SUDAN BLACK B AND ITS POTENTIAL USE IN COMPARATIVE ANATOMY

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ABSTRACT—The Sudan Black B method for staining nerves in whole, cleared specimens is summarized as recently modified. Effects of long-term storage on stained specimens, and techniques of lighting and dissection to aid study of overstained or thick specimens are discussed.

The potential usefulness of studies of distal branches of nerves was assessed by comparing intraspecific and interspecific variation in three species of frogs. Several consistent interspecific differences were found in the nerves of the tongues of the frogs, and we conclude that there is significant potential for the advancement of comparative anatomy and comparative physiology in studies of distal branches of nerves.

Introduction

The study of the comparative anatomy of nerves of vertebrates is a neglected area. In particular, the potential that exists in studies of distal branches of nerves has not been realized. A major reason is that there has not been an efficient technique available for examining the location and branching patterns of nerves in whole (as opposed to sectioned) cleared vertebrate specimens.

The main advantages of the Sudan Black B method, which we have developed, are rapidity of the staining step, reliability, ease of use, low cost both in materials and time, compatibility with alizarin staining of bone in the same specimens, and flexibility in that either freshly preserved or museum specimens in storage for extended periods of time can be successfully stained (Filipski and Wilson, 1984, 1985). In this paper we summarize the technique, which we have recently simplified compared with the method presented by Filipski and Wilson (1984), and discuss some of the problems and potential applications of the method.

There are two serious problems that we have encountered so far. The first is that some specimens, particularly the young of some species of fish, have nerves that stain very lightly, possibly because the myelination of the nerves is at an early developmental stage. The solution that we have found is to use adult specimens of these species where possible, although for species that reach large body sizes this is impractical.

The second problem is overstaining. Some species of fish appear to have a great deal of oil in their tissues, and because Sudan Black B actually stains the myelin sheath of the nerves, we have not been able to remove excess oil from tissues without removing the lipids upon which the stain acts in the myelin. For these and other specimens, the stain is taken up not just by nerves but by other tissues. As a result, it can be difficult to see, and especially to photograph, the (black) nerves against the darkly stained background tissues. Lighting techniques that we have found useful in such cases are also discussed in this paper.

Finally, in order to illustrate the potential of the technique for studies of the comparative anatomy of nerves, we present a brief example from three species of frogs in which we investigate the consistency of branching patterns of distal branches of certain nerves.

Stain Procedure

Five solutions are required: stain, maceration (trypsin and distilled water), 70% ethanol, 40% glycerine, and 70% glycerine (Fig. 1). These solutions are made as in the original study (Filipski and Wilson, 1984). However, the KOH washes of our earlier paper have been replaced with distilled water washes. We have found water to be as effective as KOH, with the added advantages of greater simplicity of technique and increased gentleness with delicate specimens (Filipski and Wilson, 1985).

Fresh specimens must be fixed first in formalin (we use a 10% solution), as described by Filipski and Wilson (1984). Times given below for each subsequent step in the process are from trials with five adult museum (not recently fixed) specimens from each of three species of frogs.

Prior to maceration, remove the eyes and skin, and eviscerate all specimens to facilitate staining and subsequent study. Immerse the specimens in a distilled water bath (Fig. 1) for four days to remove formalin and alcohol. Next, immerse the specimens in the maceration solution. Remove the specimens before the tissue becomes completely translucent, an average of seven days for the frogs. Rinse the specimens in distilled water for ten minutes to remove the maceration solution. After this wash, we have successfully stained bones (Filipski and Wilson, 1985) by

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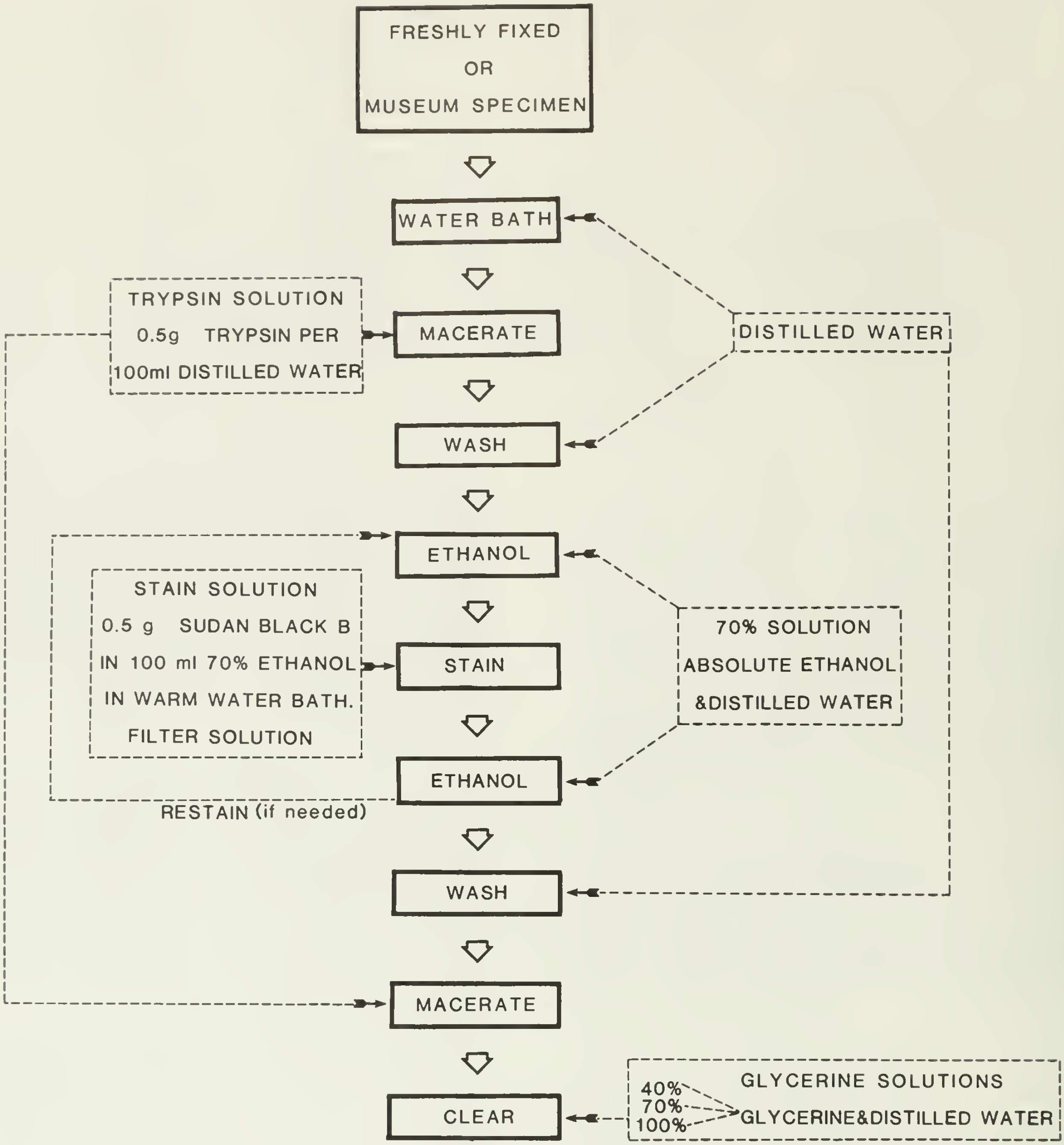

Fig. 1. Flow chart of steps in the Sudan Black B nerve-stain procedure. See text for explanation.

immersing specimens in a weak solution of alizarin for three or four days. Following the wash, or following the alizarin staining, immerse the specimens in a 70% ethanol solution (for 10 to 30 minutes, depending on specimen size) to prepare for nerve staining.

Next, immerse the specimens in the Sudan Black B stain solution (Fig. 1) and agitate gently. Length of time in the stain is extremely variable and is dependent on a number of factors such as body size, degree of maceration, and species. There are problems that can occur during the staining procedure. Overstaining is readily corrected by reimmersing the specimen in 70% ethanol and allowing the stain to be drawn out of tissues that may be overstained. A certain amount of stain is also removed from other tissues not overstained. We have found it best to remove most of the stain from the overstained specimen and to start the staining procedure anew. Often, if only part of the specimen is overstained, the overstained area can be immersed while keeping the correctly stained areas out of the stain solution. It is most important, especially in the case of smaller specimens, to constantly monitor the extent of staining by removing the specimen from the stain, immersing briefly (about 10 seconds) in 70% ethanol and examining the specimen under a microscope. The critical point to note is whether the finest peripheral nerve branches are stained. We have found with the frogs that it is useful to compare the abdominal wall and the hindlimb. The abdominal wall will show staining of fine nerve fibres in a superficial area, while the hindlimb will show the extent of staining in a deep muscle mass. Should the nerves not show the characteristic blue-black colour, reimmerse in the stain solution and repeat the procedure.

After staining, destain the specimens in several baths with gentle agitation, first by immersion in 70% ethanol. This primary destaining quickly colours the solution with excess stain. Specimens are transferred to fresh ethanol solutions until they become translucent again and the larger nerves become visible. The duration of destaining is not as critical as the duration of staining. If specimens are not sufficiently destained, later steps in the process will correct any overstained areas. We prefer to remove specimens from the ethanol washes after two changes of solution and to allow the secondary maceration to remove the excess stain with less trauma to the delicate specimen. In preparation for secondary maceration, immerse specimens overnight in distilled water to remove the ethanol. If it is desirable to stain bones, and if they were not stained at the earlier stage as described above, it is possible to stain them with alizarin after this wash step.

Begin secondary maceration by immersing the specimens in a fresh maceration solution. Allow specimens to reach complete maceration. Stain initially rapidly colours the maceration solution, necessitating a daily change of solution, but often, as with the frogs used in this study, the specimens remained in the solution for only one day.

The final process is clearing: immersion of the specimens in progressively more concentrated glycerine solutions. Leave the specimens in the 40% solution for several hours, and in the 70% solution for 24 hours or more. Some specimens do not release excess stain readily before the clearing process. These specimens release excess stain during the clearing process, and even the most heavily stained specimens lose excess stain during prolonged storage in the final 100% glycerine solution.

Long-term storage of specimens does not appear to have marked detrimental effects. A number of our specimens have been in storage in 100% glycerine for a period of four years, with only a slight yellowing of the surrounding tissues. The nerves themselves, although no longer as dark, are still readily visible and in many cases are easier to examine because all of the excess stain in surrounding tissues has been removed.

Lighting and Dissection with Thick or Overstained Specimens

With thick specimens, or those that have excess stain, the use of certain lighting techniques can help, both for direct study of the nerves and for photography. The technique that has been most successful involves the use of double goose-neck fibre-optic light pointers. One of the pointers can be moved into any position under the specimen to allow transmitted illumination of the dark areas of the specimen. The stained nerves are opaque and rendered more visible when the background tissues are lighted in this way. The second pointer simultaneously provides incident illumination at an oblique angle. This tandem lighting technique often gives the photograph the appearance of having a third dimension.

A second technique that we have found to be useful for study or photography of thick or overstained specimens is dissection. This is most useful for tissues deep within the body, or for organs and body parts, such as tongues, jaws, and limbs, that can be readily removed without distortion. In the case of deep tissues, overlying nerve fibres and residual stain in overlying tissues can interfere with normal viewing of fibres in the deep areas. Conversely, the extensively stained background (brain and large cranial nerves) in the head can interfere with study or photography of the more superficial distal branches of nerves to the jaws. Dissection of parts such as limbs also facilitates orienting the specimen for study or photography.

Potential for Comparative Anatomy

In order to assess the potential of the Sudan Black B staining procedure for studies emphasizing the comparative anatomy of distal branches of nerves, rather than the more usually emphasized larger branches of cranial nerves, we conducted trials on five specimens of each of three species of frogs in the genus *Rana*. The main question to be answered was whether significant interspecific, as opposed to intraspecific, differences could be found in the distal branching patterns of nerves.

The specimens used were all adult museum specimens that had been in storage in the Museum of Zoology, University of Alberta, for more than five years: *Rana sylvatica*—UAMZ 1522 (lot); *Rana pipiens*—UAMZ 1871–1874, 1878; and *Rana pretiosa*—UAMZ 1480–1484.

Following the staining and clearing procedure, the tongue was dissected from the specimens to facilitate photography of the area. Comparisons are more easily made among photographs, which can be viewed as a group, than among specimens, each of which must be viewed individually under the microscope. In comparing the location and branching patterns of the distal nerves of the tongue in the three species, we found some consistency within the species and differences among them (Fig. 2).

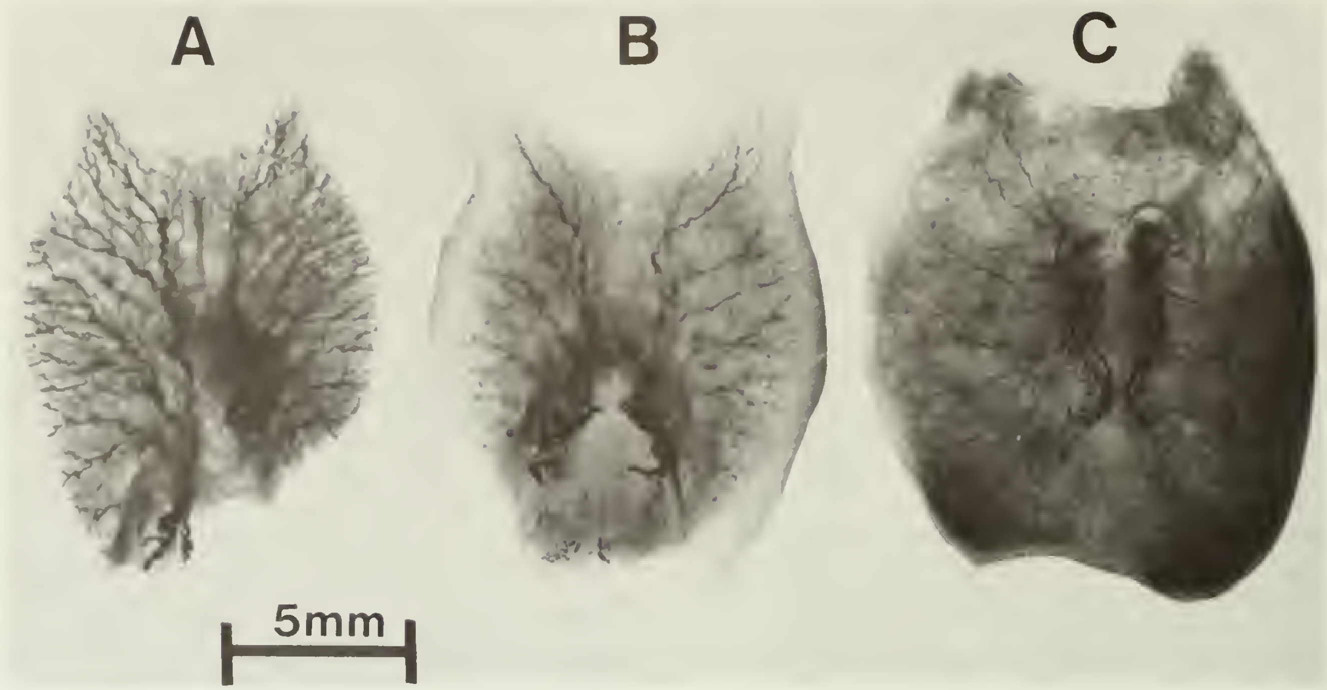

Fig. 2. Examples of frog tongues dissected from specimens that were stained using Sudan Black B. A) *Rana pipiens*; B) *Rana pretiosa*; C) *Rana sylvatica*. Distal towards top of page.

The branching of the main fibres entering the tongue begins before the fibres enter the free part of the tongue in *Rana sylvatica* and to a lesser extent in *Rana pretiosa*. In *Rana sylvatica* three pairs of fibres (Fig. 2C) can be seen entering the base of the tongue, while in *Rana pretiosa* (Fig. 2B) two pairs of fibres enter. In *Rana pipiens* (Fig. 2A) only one pair of fibres enters the tongue.

In addition, the density of the fibres within the tongue is markedly different. The densest innervation occurs in *Rana pipiens* (Fig. 2A), with less density in *Rana pretiosa* (Fig. 2B), and least density in *Rana sylvatica* (Fig. 2C). A third consistent interspecific difference is that in *Rana pipiens* (Fig. 2A) the fibres extend closer to the periphery of the tongue than they do in the other two species.

Use of these differences in systematics would depend on the purpose of the study. For species-level systematics, these features can be used to distinguish the species. For phylogenetic studies, comparison with related frog species could indicate the polarity of the characters, permitting their use in phylogenetic reconstruction.

Conclusion

A reliable nerve stain for whole cleared specimens is potentially useful in both comparative anatomy and comparative physiology. In comparative anatomy, interspecific differences in both proximal and distal branches of nerves can provide a useful and largely unexplored source of data for studies in phylogeny and taxonomy, most of which have traditionally been based upon features of the skeleton. The nerves also provide important information about homologies of muscles and foramina. We believe that comparative anatomical research that combines information about the skeleton, muscles, and nerves is now practical.

Applications in comparative physiology are also apparent. For example, it is now a simple matter to map pathways of and assess interspecific and intraspecific variation in nerves that are the subject of physiological experimentation. Moreover, biomechanical studies of organs such as the tongues of frogs can be interpreted more readily in light of the anatomy of their nerves and what these nerves indicate about the functional divisions of the muscles.

Acknowledgements

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A METHOD OF PREPARATION OF ANURAN OSTEOLOGICAL MATERIAL

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ABSTRACT—To prepare an anuran skeleton, the frog is skinned, the viscera are removed, and the bones are picked clean with forceps. The skull, vertebral column, and pectoral girdle, arms, hands, and feet are left intact. The pectoral girdle and hyoid may be cleared and double stained and kept as wet preparations. Bleach is used for the final cleaning, and then the skeleton is washed and allowed to air dry.

Introduction

The study of osteological material is crucial to an understanding of the evolutionary, morphological, and systematic relationships among frogs. Good anuran osteological specimens are not common in museum collections, but can be prepared from alcoholic specimens. This procedure, developed under the direction of Dr Linda Trueb of The University of Kansas (KU), has been perfected during the preparation of approximately 600 dry anuran skeletons. With minor modifications, it also could be used to prepare skeletons of other amphibians. Nomenclature follows that of Duellman and Trueb (1985).

Before you begin to prepare a specimen, spend some time examining a skeleton or at least some illustrations of skeletons to become familiar with the shapes and arrangements of the bones and cartilages. Excellent detailed illustrations of amphibian skeletal and muscular features can be found in Duellman and Trueb (1985).

TOOLS

A pair of small, sharp scissors with pointed tips, a pair of blunt-tipped forceps, and a pair of fine-pointed forceps are needed. A binocular, dissecting microscope is sometimes useful when preparing small specimens.

Should suitable fine-pointed forceps not be available, Alan Savitzky (pers. comm., 1976) suggested that the points could be ground to the desired shape with a whetstone.

PREPARATION OF SPECIMENS

Both preserved and fresh specimens can be used. Skeletal components should be stored in 70% EtOH during processing. Specimens in formalin should be soaked in water for 24 hours and then rinsed prior to preparation.

Before processing begins, notes should be made concerning the colour and soft morphology of the specimen. Always record the snout–vent length and the sex.

SEPARATION INTO SKELETAL UNITS

Begin by slitting the skin midventrally from the vent to the mandible, taking care not to penetrate the body cavity. The second incision should cross the pectoral region and arms to the palmar surfaces of the hand and thence down each digit. The hind limbs and feet should be incised similarly. The entire skin can now be pulled off. If the specimen is fresh (i.e., not preserved), the skin can be dried to preserve color (Juszczyk, 1952).

Next cut through the body wall around the abdominal cavity starting behind the axilla. Do not cut the sternum and omosternum. Tease the muscles away from the pectoral girdle and sternum with forceps. Cut the rectum free from the vent, and gently pull the entrails out of the abdominal cavity. Cut the esophagus and trachea posterior to the coracoids. The digestive and reproductive tracts of the specimen should be saved as wet preparations if needed by other researchers.

With the use of forceps to free the muscle fibres and ligaments associated with the articulation of the ilia and the sacral diapophyses, the posterior appendicular skeleton can be disarticulated. Pull the ventral thigh muscles of the femur distally (from the pubis towards the knee) to expose the joint between the femur and the acetabulum. Usually there is a cartilaginous rim around the acetabulum that can be damaged with forceps. Dislocate the condyles of both limbs from the acetabulum. Separate the femur from the tibiofibula, and then the tibiofibula from the tarsus.

Next, separate the anterior portion of the skeleton into workable units. Begin working from the base (near the glenoid fossa) of the scapula on either side, pulling the muscles loose with forceps to expose the ventrolateral surface of the scapula. The suprascapula is mostly cartilaginous and can easily be broken. Next, working from the coccyx, remove the muscles that run along the vertebral column to the back of the skull. Remove the muscles that attach the suprascapula to the axial column and skull a few strands at a time to avoid tearing the

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cartilaginous edge. Insert the forceps beneath the suprascapula and gently work it loose.

Open the mouth of the frog and loosen the articulation of the mandible on either side of the head by carefully cutting the adductor muscles that attach to the lower jaw and then clipping the depressor mandibulae running from the posterior end of the mandible to the top of the skull. It is easy to damage the posterior, ascending, threadlike cartilaginous processes of the hyoid apparatus located in the floor of the mouth between the pectoral girdle and the mandible. If the specimen's mouth cannot be opened, the mandible must be reached from the outside. In order to do this, cut the skin posterior from the corner of the mouth. Carefully insert the scissors between the upper and lower jaws and clip the muscles anterior and posterior to the jaw articulation. If this does not free the mandible, approach it from the back, being careful of the hyolaryngeal apparatus.

Once the mandible is disarticulated, but still attached to the pectoral girdle, pull the skin loose from the roof of the mouth with forceps, working around the inner margin of the upper jaw. If vomerine teeth are present, pull the skin away from them without dislodging the teeth. The pectoral girdle and lower jaw with hyolaryngeal apparatus intact can now be pulled loose from the skull and vertebral column.

The mandible, with floor of the mouth, tongue, hyolaryngeal apparatus, and a portion of the esophagus and trachea attached, should now be pulled free from the pectoral girdle.

At KU, we find it best to clear and stain the entire pectoral girdle and hyoid apparatus because they become severely distorted as they dry. Refer to Dingerkus and Uhler (1977) for instructions on clearing and staining.

Begin to separate the skull by removing the remaining muscles along the vertebral column, working from the coccyx towards the skull. In many species, the columella (= stapes) can be dislodged easily from its precarious attachment to the operculum and auditory capsule. As more tissue is removed, the cervical vertebra can be twisted slightly about its articulation to the occipital condyles. Once all the tissue is removed, grasp the skull carefully in one hand, and the axial vertebra between thumb and finger of the other hand, and slowly bend the vertebral column downward. It is often necessary to work with forceps to free the cervical vertebra, and usually some twisting is required to free the skull from the vertebral column.

MECHANICAL CLEANING OF THE SKELETON

The long bones are cleaned by forceps or by gentle rubbing with the thumb to remove clinging muscle fibres. Do not scrape or scratch the bone. Smaller bones, such as metacarpals and metatarsals, should be carefully picked clean with forceps. The pelvis is cleaned in the same way as the long bones, but take care not to damage the cartilaginous rim of the acetabulum.

Begin cleaning the feet by removing any pieces of skin that remain. The muscles, ligaments, and tendons associated with the bones of the hands and feet must be removed carefully so that the articulations and alignment of the ankle, wrist, and phalangeal elements will not be disturbed. Preferably, the hands and feet should be left fully articulated, so a certain amount of connective tissue must be left on the bones. Skin covering the terminal phalanges of both hands and feet is often difficult to remove without pulling the terminal phalanges loose, especially in those species having intercalary cartilages. To remove the skin covering the terminal phalanges of specimens having modified shapes of this element, free the skin from the bone, then clip the skin off at the intercalary cartilage. If a prepollical spine or nuptial excrescence is present on the hand, or a prehallux on the foot, enough tissue should be left to assure its attachment.

The vertebral column must be picked clean with forceps. A few anurans have bony shields attached to the neural spines. Fine-pointed forceps can be used to clean under these shields. The transverse processes of the vertebrae often have cartilaginous extensions which are easily broken off. Ribs articulate with the second, third, and fourth presacral vertebrae in discoglossids and pipids, and sometimes also with the fifth presacral in leiopelmatids (Duellman and Trueb, 1985). The soft cartilage of the ribs of the Ascaphidae and Discoglossidae becomes very distorted if dried, so the entire vertebral unit must remain as a wet preparation if the ribs are to be saved. It is preferable to clear and stain it. The ribs of pipids are ankylosed to the transverse processes in adults and usually will withstand drying. Fine-pointed forceps can be used to grasp the spinal cord and pull it out of the vertebral column.

The lower jaw can be cleaned with forceps, using caution around the mentomeckelian bones at the mandibular symphysis.

Begin cleaning the skull by removing the remaining skin from the roof of the mouth. Skin covering the palatines in the roof of the mouth should not be removed except on very large specimens (which have heavier, sturdier skulls).

Remove the eyes by pushing the eye slightly out of the orbit from the roof of the mouth and severing the optic nerve and orbital muscles; take care not to damage the optic foramen in the lateral wall of the neurocranium. The eye can then be pulled from the orbit through the roof of the mouth.

Remaining tissue on the back of the skull now should be removed to expose the columella. In some species the columella is fairly firmly attached; however, in most it is loose and can be dislodged accidentally while removing the tympanum and muscles extending between the suprascapula and the skull and the columella itself.

The composition of the area around the external nares usually is soft and consists of the cartilaginous nasal capsule, which is variably roofed by the nasal, and the septomaxilla (internal to the capsule). Except with very large specimens, removal of only the skin from this area is sufficient. The braincase can be cleaned by removing the contents with forceps or using a Pasteur pipet on an air line. Clean remaining tissue from the rest of the skull with forceps.

Special problems arise with specimens that exhibit dermal ornamentation. Duellman and Trueb (1985) recognized three types of ornamentation: exostosis (ridges, crests, spines, etc.); casquing ("helmeted" appearance); and co-ossification (skin fused to underlying bone). Generally speaking, for specimens exhibiting exostosis or casquing, the skin can be carefully scraped loose around the bone projections with forceps. Because hard scraping will incise the bone, not all of the skin can be removed in this way, and the remainder must come off during chemical cleaning. Only chemical cleaning will remove the skin from most species showing co-ossification (e.g., *Bufo*).

The main difficulty in cleaning the pectoral girdle is avoiding damage to the articulation of its two halves. Clean the hands first with a method similar to that used for the feet.

Firmisternal pectoral girdles usually present no problems aside from the potential of damage to cartilage of pre- and post-zonal elements. However, arciferal girdles, with their overlapping epicoracoid cartilages, are prone to damage. With both types of girdles, tissue must be removed in small amounts to avoid destruction of the sternum and omosternum, because they are mainly cartilaginous. When cleaning the pectoral girdle, alternate between sides and between dorsal and ventral surfaces, so that key areas of articulation are not weakened. Drying of the skeleton will cause distortion in the shapes of the scapula, sternum, and omosternum, so any detailed drawings of the shape of these structures must be made before chemical cleaning and drying. It is usually preferable to clear and stain the pectoral girdle.

CHEMICAL CLEANING

Skeletons may be cleaned chemically with bleach in which sodium hypochlorite is the active agent (Sanders, 1953). Use a small amount of full-strength bleach as a working solution, deep enough for the submergence of each portion to be cleaned. A few seconds to one minute of submergence is usually sufficient. Longer periods of submergence tend to make the bones greasy and cause disintegration over time. The sodium hypochlorite acts quickly on cartilage. With specimens exhibiting dermal ornamentation from which skin cannot be removed efficiently by mechanical means, and to avoid prolonged submergence of the entire skull in the chemical solution, the chemicals may be applied to the areas of the skull to be cleaned with an eyedropper or a piece of cotton or paper towel which can be pressed against the skull and allowed to stand for a few seconds to a minute. The softened skin can then usually be removed with finely pointed forceps.

When skeletal units are removed from the bleach solution, they must be submerged immediately in 70% EtOH, then in ammonia, and finally rinsed in cold water (George Pisani, pers. comm., 1979), in water with a few drops of glacial acetic acid added (Jay Savage, pers. comm., 1984) or cold water for 24 hours.

DRYING AND STORAGE

Once rinsed, the various skeletal units should be placed on paper towels to dry at room temperature for 24 hours before being stored. Skeletons can be stored in small plastic or cardboard boxes with well-fitting lids. Wet preparations of skeletal units, such as vertebral columns with ribs or hyolaryngeal apparatus, should be stored in a tightly capped vial. Any vials stored with dry skeletal material should be secured so that movement will not damage fragile structures. Small loose bones may be kept in clear gelatin capsules with the skeleton.

Labels are needed for the lid, inside of the box, and for any vials. Each label should bear the scientific name, museum number, sex, snout-vent length, and locality of the specimen.

A notation should be made in the appropriate catalog that the specimen has been prepared as a dry skeleton, and note which, if any, parts of the specimen are maintained as wet preparations.

Acknowledgements

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AN ULTRASONIC TECHNIQUE FOR CLEANING SPECIMENS

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Abstract—Preserved specimens with foreign particles and dirt attached are often found in museum collections. Cleaning these specimens for illustration or identification purposes is sometimes difficult. Fine brushes and needles often break setae or other delicate structures. We have found that an ultrasonic cleaner with an attached timer is an ideal apparatus to help with this cleaning problem. Animals were put into a small glass beaker with distilled water. A few seconds or a few minutes in the ultrasonic cleaner removed most of the dirt particles. This apparatus can be used to clean crustaceans, insects, myriapods, polychaetes, spiders, larval fishes, and other small-bodied animals.

RESTORING DRIED-UP INVERTEBRATES: AN UPDATE

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Abstract—Decon 90 has been used to restore dried-up Crustacea (Amphipoda, Decapoda, Isopoda) and other invertebrates (Annelida, Cnidaria, Echinodermata, Mollusca). This work is an update on the two techniques presented in *Proceedings of the 1981 Workshop on Care and Maintenance of Natural History Collections*, 1983.

A CHEMICAL METHOD OF FLOWER PRESERVATION

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ABSTRACT—A process for perserving most kinds of flowers while retaining the natural colours has been developed. The flower is dehydrated in a mixture of at least one dehydrating alcohol, a carboxylic acid, a urea-containing compound, an alkaline citrate, at least one silicone resin (optional), an alkaline formaldehyde sulfoxylate, aluminum or magnesium sulphate, cupric or other transitional metal sulphate, and a buffer for pH 5–7 such as an alkaline phosphate, a lower carboxylic acid, and/or phenol. Following immersion, the flower is dried and, if desired, coated with a silicone resin.

Introduction

The preservation of flowers for museum specimens, science, education, and decorative and ornamental use has been practised for many years. Various processes for such preservation have been described in the literature (Lutz, 1969; MacDermot, 1973; Steedman, 1976a and b; Romero-Sierra and Webb, 1983; Hangay and Dingley, 1985).

There are three commonly used methods that are considered superior. In each a specimen is either: a) dried between blotters; b) dried by embedding in salted silica gel or sand (MacDermot, 1973); or c) immersed in a dehydrating solution (Lutz, 1969; Hangay and Dingley, 1985). These methods are not, however, entirely satisfactory. The delicate natural colours of the flowers tend to fade and the flowers become brittle, fragile, and susceptible to damage in extremes of temperature or humidity so that special handling and storage techniques are required.

Without special techniques the natural beauty of the blooms is quickly lost and the flowers are no longer useful for display or education. Indeed, storage in sealed bells or embedding in plastic have heretofore been the only practical methods of storage and handling. Further, in order to treat flowers of different colours it was necessary to use a variety of treatment solutions as there was no single treatment solution suitable for all colours (Lutz, 1969).

Our objective is to describe a process and a single treatment mixture for the preservation of most colours and varieties of flowers which results in naturally coloured flowers that retain their freshness and beauty for six months or several years without special handling and storage in environments of varying temperature and humidity.

Materials and Methods

Our process is simple and straightforward. A fresh bloom is chosen and a wire is inserted into the stem or bloom. A weight is added to keep the bloom submerged in the mixture. The vessel containing the mixture (Table 1) is placed in a water bath at a temperature ranging from 7° to 24°C. The bloom is left suspended in the bath without agitation for from 6 to 24 hours, depending upon size and water content of the bloom and the freshness of the solution.

Upon immersion in the mixture, virtually all colour seems to disappear from the petals as they undergo dehydration by the alcohols. The normal colour slowly returns as the water extracted from the flower enters the solution, this giving a useful indication of the treatment time required. Large, fleshy blooms require longer immersion and care must be taken to ensure that the bloom is immersed long enough to treat the relatively heavy and impervious receptacle.

Following immersion, the flower is removed from the mixture and air-dried at room temperature and relatively low humidity (40–50%) for 8 to 10 hours. Blooms thus treated can generally be stored and displayed without further treatment for at least 4 to 6 months, provided the temperature and humidity are suitable (i.e., up to about 27°C and 60–70% relative humidity). More stressful environments require that the blooms be stored in sealed glass domes, where they will likely last for years, or be further coated.

Dipping or spraying with a conformal coating resin, such as Dow Corning R43117 Silicone Resin alone or diluted with Dow Corning Fluid 200™ (0.65 centistokes) or other diluent, is satisfactory for this purpose. Preferably the coating is applied by dipping the bloom into the resin

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thinned with a diluent such as xylene at a temperature in the range of 10° to 27°C for a few minutes. The coated bloom is then dried at room temperature for several hours to cure the resin coating. The resin cures to a clear shiny coating and leaves the bloom relatively pliable.

A shiny surface is often desirable, but if a matte surface is desired this can be sprayed on. The thickness of the coating has a bearing on the appearance of the bloom—thin coatings lend a natural and delicate appearance to the bloom, while thick coatings produce sturdy blooms often of special beauty.

Results

Teaching aids prepared with our preservation method have been used extensively in the Department of Biology of Queen's University to test the efficacy of the treatment. Students as well as teaching staff have found them far superior to other teaching aids.

Table 2 shows that Mixture A is preferred for general use. Modification can, of course, be made for blooms of specific colours. Thus, elimination of sodium phosphate (Mixture B) results in relatively faded colours. Additional sodium formaldehyde sulphoxylate (Mixture C) is deleterious to yellow, red, and blue flowers but appears beneficial to white flowers. Increased citric acid (Mixture D) damages blue African violets and fades yellows while enhancing red flowers. Decreasing thiourea (Mixture E) fades all colours, especially dark blue African violets, while increasing thiourea (Mixture F) seems to serve no useful purpose. Increasing aluminum sulphate (Mixture G) causes spotty red and blue flowers as it produces a burning in the cellular structure of the petals. Reduction of aluminum sulphate (Mixture H) has little noticeable effect. Decreasing sodium citrate (Mixture J) causes fading of blue colours. Increasing sodium nitrate (Mixture K) has no noticeable affect as most of the additional chemical does not dissolve. Reduction of cupric sulphate (Mixture L) has little effect on the blooms but bleaches the stems. Increasing cupric sulphate (Mixture M) merely results in the additional chemical being left undissolved without effect on the blooms. We believe, however, that excess cupric sulphate improves the aging properties of the mixture as it appears to draw water from the alcohols. Reducing phenol (Mixture N) fades both red and yellow flowers. Excess phenol (Mixture P) enhances all blooms, especially red up to about 62 ml per litre, but amounts exceeding this cause darkening, indicating a burning effect. Additional silicone oil or resin (Mixtures Q and R) has little effect on the colour or texture of any of the blooms but lengthens the dehydrating times, because of the isolating properties of these compounds.

Discussion

To preserve a bloom, all of its water must be eliminated and many monohydric alcohols, in particular tertiary butyl alcohol, are extremely efficient dehydrating agents. Although one or more such dehydrating alcohols may be used, we have found that a mixture of tertiary butyl alcohol, 1-propyl alcohol and 2-propyl alcohol is particularly effective for the treatment of flowers.

The 3-butanol can vary from 175 ml to 575 ml per litre of treating mixture, with a preferred concentration of about 375 ml. Generally, use of more 3-butanol relative to the other two alcohols shortens the period of time of immersion.

The dehydrating properties of 3-butanol are so great that the final product bloom tends to be brittle if not compensated for by the inclusion of a silicone fluid, such as Microfil™ MV-diluent, in the formulation. The upper limit of 3-butanol, relative to the 1-propanol and 2-propanol, is controlled at least in part by the fact that 3-butanol freezes at 24°C.

The 1-propanol and 2-propanol components are in themselves effective dehydrants and modify the harsh effects of 3-butanol used as described above, without interfering with its effectiveness. The amount of these components is not critical to the mixture, provided modifications to the other components are also made.

Sodium phosphate dibasic or other alkaline phosphate, such as potassium or ammonium phosphate, is preferably added to the formulation to control or buffer the pH. It has been found that pH control of the formulation is necessary for consistent results and preferably the pH should range from 6 to 6.5. If no green is present in the bloom, the pH may be as low as 5. For the treatment of green plants, pH 7 is preferred. Most blooms to be treated include a green stem and for this reason alone the preferred pH ranges from 6 to 6.5. We have found, however, that depending upon the exact mixture employed and the optional constituents employed, pH can be controlled without the use of an alkaline phosphate buffer provided that a sufficient quantity of a lower carboxylic acid such as propionic acid and/or phenol is added.

Sodium or other alkaline formaldehyde sulfoxylate is optionally added to the formulation for its bridging properties and is particularly useful in the treatment of white blooms. It speeds up the setting of the colour and although omitting it does not essentially change the results, the overall quality of the preserved blooms, especially white flowers, is reduced.

A carboxylic acid is employed, primarily as a colour preservative, for red, pink, yellow, and white. While suitable acids include tartaric, salicylic, and carbolic acid, citric acid is preferred. Although the amount can be varied within the limits we describe, a carboxylic acid such as citric acid cannot be eliminated. Too low a concentration

Table 1 Preservation formulae for flowers

An asterisk indicates components that were only partly dissolved.

Component	Mixture A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
3-butanol (ml)	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375
1-propanol (ml)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
2-propanol (ml)	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Sodium phosphate (g)	12		12	12	12	12	12	12	12	12	12	12	12	12	12	12
Sodium formaldehyde sulphoxylate (g)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Citric acid (g)	5	5	5	10	5	5	5	5	5	5	5	5	5	5	5	5
Thiourea (g)	10	10	10	10	5	20*	10	10	10	10	10	10	10	10	10	10
Aluminum sulphate (g)	5	5	5	5	5	5	10	2.5	5	5	5	5	5	5	5	5
Sodium citrate (g)	6	6	6	6	6	6	6	6	3	12*	6	6	6	6	6	6
Cupric sulphate (g)	1	1	1	1	1	1	1	1	1	1	0.5	2*	1	1	1	1
Microfil MV-diluent (ml)	63	63	63	63	63	63	63	63	63	63	63	63	63	63	80	63
Microfil 132 Clear (ml)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	50
Phenol (88%) (ml)	37	37	37	37	37	37	37	37	37	37	37	37	19	62	37	37

Table 2 Effects of preservation formulae on some flowers

Mixture	Red rose	Yellow mum	White mum	Blue fuschia	Red fuschia	Yellow hibiscus	Pink hibiscus	Red maple	Blue African violet	White geranium	Pink geranium
A	good colour	good colour	good colour	good colour	good colour	good colour	good colour	good colour	good colour	good colour	good colour
B	——retained colour, but pale and lacking "health"——										
C	faded	faded white spots	good	faded	faded	faded white spots	faded	faded	pale	good	faded
D	good	some fading	good	damaged	good	some fading	good	good	damaged	good	good
E	pale	pale	pale	pale	pale	pale	pale	pale	pale	pale	pale
F	good	good	good	good	good	good	good	good	good	good	good
G	spotty	good	good	spotty	spotty	good	spotty	spotty	spotty	good	spotty
H	good	good	good	good	good	good	good	good	good	good	good
J	good	good	good	faded	good	good	good	good	faded	good	good
K	good	good	good	good	good	good	good	good	good	good	good
L	——good, but stems turned light green——										
M	good	good	good	good	good	good	good	good	good	good	good
N	faded	faded	good	good	faded	faded	good	faded	good	good	good
P	enhanced colour	good	good	good	enhanced colour	good	enhanced colour	enhanced colour	good	good	good
Q	——good, but slowed dehydration time——										
R	——good, but slowed dehydration time——										

causes the colours to fade, especially in red flowers. Too high a concentration can cause burning or colour changes, particularly in the green portions of the flower.

A urea-containing compound is essential to prevent loss of pigments from the blooms and, when used together with citric acid and sodium citrate, it increases the efficiency of those chemicals and prolongs the active life of the mixture. Thiourea is a preferred urea-compound. Insufficient thiourea, or other urea-containing compound, causes colours to lack their original fresh beauty. Some colours may even change completely, as for instance a blue orchid that may turn to a sickly red or pink. Excessive thiourea does not have any deleterious effect except to increase the cost of the formulation.

Aluminum sulphate, which appears to affect the overall quality of the colours of the blooms, is an optional constituent in the formulation. Too much aluminum sulphate (more than 100% excess) may cause spots resembling burns on red and blue petals. Magnesium sulphate may also be employed but tends to be hygroscopic.

Sodium or other alkaline citrate is added as a colour preservative for blue, purple, and orange blooms and in conjunction with thiourea. Omission of sodium citrate causes the colours to fade. Excess sodium citrate does not affect blue, purple, or orange blooms but red and pink blossoms are adversely affected.

Cupric or other transitional metal (Fe, Ni) sulphate is an optional constituent added not only to fix the colour of the blooms but also to draw away moisture which gathers at the bottom of the treatment tank through repeated treatment of the blooms, thereby extending the life of the mixture. Excess cupric sulphate tends to precipitate and there is some risk of burns to the blooms.

A silicone fluid, such as a silicone rubber injection compound sold under the name Microfil^{TM} (MV-diluent) by Canton Biomedical Products Inc., Boulder, Colorado, or dimethyl siloxane polymer sold under the name Dow Corning 200^{TM} by Dow Chemical Corporation, is preferably added to the mixture to protect the final product from variations in humidity and temperature. The silicone fluid also reduces the brittleness of the bloom caused by the alcohol dehydrating agents. The silicone fluid impregnates the tissue of the bloom as it is being preserved and also strengthens the petal-receptacle junction. Reduction of the silicone fluid to below about 30 ml per litre results in inferior products from the point of view of stress resistance, but an excess of the silicone fluid has no effect and merely increases the cost of the formulation.

To further protect the preserved bloom against humidity and improve its water repellance, a silicone polymer such as Microfil^{TM} MV-132 Clear, sold by Canton Biomedical Products Inc., or SYL-OFF^{TM} Dow Corning Fluid 1107, may be used. We emphasize that neither the silicone fluid nor polymer play a part in colour preservation, but they do affect the physical and biological properties which allow a flower to withstand stresses, such as rough handling, humidity, and temperature.

Phenol and/or a lower carboxylic acid may be added to the formulation to enhance the efficiency of the other constituents. They appear to act as pH buffers and as dehydrating agents. They also seem to assist in fixing colours. The preferred lower carboxylic acid is propionic acid, which is frequently present in biological tissue, although other acids such as acetic or butyric acid may also be employed. There are, however, disadvantages accruing from the use of such other acids. The range of acetic acid for example, is very limited and an excess "burns" the bloom very easily. Also, butyric acid has an objectionable smell that is frequently difficult or impossible to eliminate from the treated bloom.

The amount of phenol and/or propionic acid to be added depends upon the result desired and upon the quantity of other additives in the solution. Not only do the phenol and/or propionic acid act as buffers but also they affect the colour balance, particularly of reds, in the bloom. For example, propionic acid tends to darken red blooms, while phenol lightens them. A mixture of propionic acid and phenol makes the colour more vivid.

Many of the solid compounds in the formulation are insoluble or only sparingly soluble in the organic liquids of the mixture and have a propensity to settle out. We suggest that the solid compounds enter solution by way of the water extracted from the blooms as they dehydrate.

Safety Precautions

During treatment chemicals are always handled with gloves and under a fume hood as standard procedure. Furthermore, the flammability of alcohols is taken into consideration.

Another issue related to potential health hazards concerns the possibility of risks posed by treated specimens to users, for example, students, teachers, and the public in museums.

The amount of volatile substances released by a flower preserved in a formula other than F or P is neglible and constitutes no problem of toxicity. However, we advise that in cases of vast quantities of preserved specimens in a diorama, a preliminary study be conducted to analyse the decay curve in time of fumes released. We are presently undertaking such a study. For formulae F and P we recommend a period of two weeks for air-drying.

We have conducted tests to evaluate the flammability of preserved specimens as compared to artificial silk flowers and specimens prepared according to conventional methods (e.g., with silica sand). Flowers prepared with our method were demonstrated to have the lowest flammability.

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PROGRESS IN THE FREEZE-DRY PRESERVATION OF BIOLOGICAL SPECIMENS

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Abstract—A new methodology for the preservation of biological specimens using freeze-drying techniques has been developed. The various steps are perfusion, vascular injection of latex, evisceration, skinning, dissection, treatment of joints, wrapping and positioning (manipulation), freeze-drying, acetone wetting, silicone treatment, curing, and drying. Details of these procedures were reported at the 1981 Workshop on the Care and Maintenance of Natural History Collections. More recent experimentation using this methodology has allowed the authors to further improve it and to gain additional insight not only into potential flaws of the technique but also into their remedy. The details of such findings are itemized and described.

A CHEMICAL METHOD OF PRESERVING GREEN PLANT STRUCTURES

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ABSTRACT—A process for preserving plant structures while retaining the natural green colour has been developed. The structures are immersed in a solution of water, at least one monohydric alcohol, at least one preservative from the group comprising lower carboxylic acids, di- and tri-hydric alcohols, and sufficient buffering and mordanting reagents to control the pH and osmolality of the solution. In a preferred arrangement the structure is secondarily treated in a holding solution of glycerin and water.

Introduction

Our objective was to find a method of preserving various green plant tissues which would retain their natural colour, freshness, flexibility, and beauty for several years without special handling and storage. For a review of previously reported methods the reader is directed to a patent description (Fessenden, 1969) and literature reviews by Lutz (1969), Wagstaffe and Fidler (1968), and Hangay and Dingley (1985). We tested the methods described by these authors and found that they make various valuable contributions but fail to satisfy our demands regarding retention of shape and colour.

Our initial approach to develop a better method of preserving green plants was similar to our method for the preservation of flowers, that is, total dehydration (Romero-Sierra and Webb, this volume). We found that colour retention is far easier to accomplish with flowers than with green leaves, because chlorophyll is a more reactive and sensitive compound than flower pigments.

The cell walls of plants are composed of microfibrils which have a high capacity to absorb moisture. Absorption of moisture follows the diffusion of molecules of water vapour from the air along a water concentration gradient. This phenomenon is described by Fick's law which, *inter alia*, shows that the rate of diffusion is a function of the water concentration in the tissue and the water concentration in the air. When concentrations move in opposite directions, that is, the tissue gets drier and the air gets wetter, so the flux of water molecules equilibrates. The ability of matter to absorb water is called its "water potential", which is very high in dried plant tissue. As tissue absorbs water, its water potential is reduced and hence the amount of water held in tissue is a function of the atmospheric humidity.

When dehydrated tissue reabsorbs water, it collapses, because turgor has been irreversibly lost once the cell membranes are dead. With this water absorption, degradative processes begin by means of endogenous enzyme reactions, direct chemical reactions, or exogenous organisms such as saprophytic bacteria. Endogenous reactions following rehydration begin because cell integrity is lost with dehydration where membranes (as distinct from cell walls) are disrupted. On rehydration, a mixing of cell contents results in enzymic and nonenzymic chemical reactions.

In green leaves the following chlorophyll derivatives have been described (Daley, 1971).

1) Pheophytins are grey-brown compounds produced under mildly acidic conditions when the centrally chelated magnesium atom is removed.

2) Pheophorbides are grey-brown compounds formed when chlorophyllides, and occasionally pheophytins, are acidified. They differ from chlorophylls because both the central magnesium atom and the phytol have been removed.

3) Chlorophyllides are green compounds produced in the presence of the enzyme chlorophyllase. They differ from chlorophyll because the phytol has been removed.

4) Other derivatives include chlorophyll isomers and allomers, which are products of oxidation. They are green and spectrally identical but can be distinguished chromatographically.

Daley (1971) notes that "in killed leaves of higher plants, the actions of oxidative enzymic systems result in a. . .distinct form of allomerised chlorophyll, in which the C_{10} hydrogen has been replaced by a methoxy group. Once formed, allomerised chlorophyll can be converted to the corresponding pheophytin, pheophorbide or chlorophyllide."

None of the many experiments that we carried out with

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various methods of dehydration (e.g., treatment baths, drying in microwave ovens, conformal coating) had any long-term success, particularly when the leaves were exposed after treatment to high light intensities and/or humidity. They were unsuccessful largely because of hydration which adversely affects chlorophyll and its derivatives.

We have therefore taken a different approach by attempting not to dehydrate the green tissues totally, but rather to effect an exchange process wherein the water in the tissue is exchanged with a water-bath solution containing chemical reagents which fix and preserve the green pigments. The treatment solution usually contains buffers to modify the biologically harsh effects of these reagents.

Materials and Methods

Our treatment of the plant tissue is simple and straightforward. First, a treating solution is prepared (Table 1), preferably in the order listed. The specimens are then immersed in the solution at room temperature for from 10 to 14 days depending upon the specimen.

Most deciduous leaves require less time than evergreens. Thick, tough leaves such as holly may require 30 days or more and rubber plant leaves, for example, even longer. Succulent structures (e.g., watercress) are somewhat difficult to treat because it is complicated to balance the rate of exchange of natural water with the treating solution.

Following the preservative treatment, the specimens may be air-dried and stored but are best used (for teaching or similar purposes) within two to three weeks as they tend to dry out.

To preserve the specimens for later use (i.e., spring or summer leaves for use as teaching aids in midwinter) or for permanent display, secondary treatment in a "holding solution" is required. This is a glycerin/water solution (100–700 ml glycerin per litre of water). The specimens are soaked in the holding solution for two to three weeks at room temperature and then air-dried.

Samples of treated specimens were left immersed for more than one year to test the influence of long term immersion in the holding solution.

Results

Upon immersion in the treatment bath, the leaves usually change to a lighter green. Subsequently, as the treatment solution replaces the natural water, the colour reverts to a natural colour but darkens with continued immersion.

Leaves and other vegetation prepared with our preservation method have been used extensively in the Department of Biology of Queen's University to test the efficacy of the treatment. Students and teaching staff have found them to be far superior to other teaching aids. Specimens treated by our method have been used successfully in dioramas at the British Columbia Provincial Museum in Victoria, British Columbia.

Table 2 shows that solutions A and, to a lesser extent, D are preferred for most varieties of green leaves, as there is less tendency for burning and darkening. Solution B is

Table 1 Preservation formulae for green plant structures

Component	Solution			
	A	B	C	D
Distilled water (ml)	495	500	588	495
1-propanol (ml)		125		
3-butanol (ml)		125		
2-butanol (ml)				118
Ethanol (unmatured 95%) (ml)	337			337
Formalin (ml)		36	29	
Ethylene glycol (ml)	39	143	59	
Glycerol (ml)	53		118	
Formic acid (ml)				84
Acetic acid (ml)		28.5	44	
Propionic acid (ml)	84	72	59	
Citric acid	63			63
Cupric sulfate	1.5	7.0	3.0	1.5
Magnesium sulfate	4.2		1.5	4.2
Sodium sulfite	8.4			8.4
Salicylic acid		1.1		
Sodium phosphate dibasic			3.0	
Chrome alum		1.1		
Zephiran™		2 drops		

Table 2 Effects of preservation formulae on green leaves and needles

Species	Solution A	Solution B	Solution C	Solution D
Black spruce	good green and flexible	good green (somewhat darker than A and some tendency to "burn")	good green (intermediate A and B; some burning and less vibrant green colour)	good green (similar to A but slightly brighter)
White spruce				
White pine				
Jack pine				
Red pine				
White cedar				
Red cedar				
Lilac				
Rose				
Basswood				
Horse Chestnut				
Sugar maple				
Norway maple				
Silver maple				
Manitoba maple				
King maple				
Red maple				
White birch				
Rubber plant	satisfactory green (after 30-days immersion)	satisfactory green (after 30-days immersion)	n/a	n/a
Holly		darker green		
Red Oak	fairly good green	turns brown		fairly good green
White oak	turns brown	turns brown		n/a
Thistle	unsatisfactory	n/a		better green than A
Flowering crab				
Moss	n/a		darker green	n/a

marginal in many instances, possibly because of the harsh dehydrating effects of 3-butanol, even allowing for the modifying effects of the propanol. Solution C yields results intermediate between A and B as 2-butanol is apparently not as harsh as tertiary butyl alcohol.

Some treated specimens deteriorate within a few months, but others maintain their colour and flexibility for periods of over one year and some have lasted for eight years. Further research to extend the preservation duration is in progress.

The specimens left for over a year in the holding solution did not fade or otherwise deteriorate.

Discussion

We found that a suitable treatment solution for green plant tissues must contain four essential groups of chemicals, namely, a) distilled water, b) an exchange medium, c) preservatives, and d) buffers, mordants, and modifiers.

The group comprising preservatives includes: 1) biological preservatives, 2) environmental fixers, and 3) biological fixatives.

The exchange medium is normally one or more monohydric alcohols containing from one to six carbon atoms. Such alcohols, particularly ethanol, 1-propanol, and 3-butanol, have dehydration properties. We suggest that the alcohol or mixture of alcohols causes removal of the water contained in the plant tissue and its simultaneous replacement by the chemical-containing water of the alcohol solutions.

Tertiary butanol may damage leafy tissue and for this reason is normally mixed with a milder alcohol such as 1-propanol. On the other hand, ethanol may be used alone.

The preservatives fall into three broad categories. First, as a biological or tissue preservative, we found the lower carboxylic acids such as formic acid, acetic acid, or propionic acid, or mixtures thereof to be effective. Second, as a structural fixative, to give body to the preserved tissue and provide resistance to auto-oxidation, we found that a dihydric alcohol such as glycol, particularly ethylene glycol, or a trihydric alcohol such as glycerol (1-, 2-, 3-propanetriol) or mixtures thereof, is effective. Third, it is desirable, but not essential, to include a biological fixative such as formalin.

The fourth group of chemicals is referred to as "buffers, mordants, and modifiers" and includes citric acid, sodium phosphate dibasic, magnesium sulphate, cupric sulphate, chrome alum, and sodium sulfite, and mixtures thereof in relatively small proportions. The amount of each chemical depends upon leaf type and the exchange medium being used. Some chemicals appear to act as mordants while others are buffers not only for pH but also for osmolality. While not considered critical, we had best results when the treatment bath was at pH 6 to 8, that is, circum neutral.

Other minor ingredients may also be added. For example, a small amount of salicylic acid has been found to preserve natural colour. In instances where the specimens are infected with fungal growths, we used a fungicide such as Zephiran™ (benzalkonium chloride).

Modifications to our mixture and process may be useful. For example, we added the water and aliphatic alcohols to a mixture of the other components with excellent results. This is advantageous for marketing and transportation, as the bulk of the mixture is water and alcohol and it may be preferable to obtain supplies locally and add them to suitably packaged solid constituents.

Glycerin softens the leaves and renders them more pliable, which is a desirable characteristic for many purposes. However, this property is not necessary for permanent museum exhibits. Thus when using solutions A or D, it may be desirable to reduce or even eliminate glycerol.

When treated specimens are intended for later use, they may be stored in the holding solution for indefinite periods of time until needed.

Safety Precautions

During treatment chemicals are always handled with gloves and under a fume hood as standard procedure. Furthermore, the flammability of alcohols is taken into consideration.

Another issue related to potential health hazards concerns the possibility of risks posed by treated specimens to users, for example, students, teachers, and the public in museums.

We have tested specimens treated in solution A in regard to toxic emission 15 days after the completed immersion period in the holding solution. The amount of volatile substances released from a bulk of such treated plants was negligible. We expect similar findings concerning specimens treated in solution D.

We have conducted tests to evaluate the flammability of preserved specimens. The results showed that our specimens had lower flammability than similar dried or untreated wilted specimens.

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COLLECTIONS MANAGEMENT WITH PARIS, THE COMPUTER SYSTEM OF THE CANADIAN HERITAGE INFORMATION NETWORK

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ABSTRACT—The Canadian Heritage Information Network (CHIN) is a branch of the National Programmes Component of National Museums of Canada. It provides the PARIS computer system as a tool for collections management using institutional data bases, and for information sharing using National Data Bases and other automated reference files. CHIN presently serves 156 clients and holds over 2.6 million records, including over 200 000 records on the Humanities National Data Base.

Introduction

The mandate of the Canadian Heritage Information Network (CHIN) is to provide a collections management service for client institutions, a national inventory of collections, and an advisory service on new technology for the Canadian museum community. CHIN recognizes the varying attitudes among museums as to what constitutes collections management, and provides services enabling them to manage their collections individually.

The computer system in use at CHIN is called PARIS (Pictorial and Artifact Retrieval and Information System). CHIN presently has a network of 156 client institutions, including National Museums of Canada as four. Of these, 44 have terminals or micro-computers or plan to obtain comparable hardware in the near future. Sixteen museums are non-terminal users or are involved in special documentation projects. Thirteen participate only in National Data Bases. An additional 83 operate through an appropriate provincial museum; two-thirds of these have data on the system in the provincial museums' data bases.

Museums outside the network are encouraged to use CHIN's Data Dictionaries to develop standards for automated documentation and collections management compatible with PARIS for possible future inclusion in the national inventory of collections, in either the Humanities or the Natural Sciences National Data Base.

Hardware and Software

The PARIS system originally ran on a Control Data Cyber 170/720 mainframe computer, and was upgraded in February 1986 to a Control Data Cyber 180/835 with two megabytes of memory, seven gigabytes disk storage, and the ability to process 4.5 million instructions per second. Participating institutions utilize different types of hardware (terminal, printer, micro-computer, etc.) to communicate with the CHIN Cyber, depending on their budget and specific requirements. Communication with the mainframe is through Bell Canada's Datapac network, or locally, by dedicated lines.

Users are depending more and more on micro-computers to serve as the connection to CHIN. The interface between PARIS and micro-computers allows for more efficient utilization of the Cyber through the use of batch transactions. Moreover, PARIS data can be downloaded and used in the institution's word-processing, spread sheet, data base management, or statistical software packages to meet local application needs, that is, special reports, cards, labels, etc.

PARIS was first conceived by Control Data Corporation, based on the software system, BASIS, produced by Battelle Laboratories in Columbus, Ohio. Data retrieval is performed in the BASIS central system. Modules within PARIS are available for batch input, on-line input and editing, procedure files, reports, and sorting data. Additional BASIS modules, such as Thesaurus (used to control vocabulary of records) and Comp (used to perform statistical analysis on data sets), may also be implemented in the future. SPSS (Statistical Package for the Social Sciences) is available in-house for the four National Museums of Canada. A videodisc application has been developed to link PARIS data with images but, because of the costly nature of creating a videodisc, it has not been taken on by any user.

Data Bases

There are different types of PARIS data bases: institutional, national, and reference. Each record in a data base has a maximum of 10 000 characters. Data fields or elements are variable in length and number, and do not require coded data. Data can be entered in upper case, or in upper and lower case, with or without French accents.

Data can be retrieved from the full text of the record as

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it was entered by creating a set of data and displaying or printing the records (using the DISPLAY or PRINT command), listing all the data in a chosen field (using EXPAND), or taking several fields to produce a columnar format (using REPORT DISPLAY). Specific terms can be retrieved from the data using the SCAN command. French commands are also available to the user.

Data can also be retrieved from the index, which is a listing of the contents of data fields sorted alphabetically for quick reference. The index can be browsed as one would read the index at the back of a book, using the LOOK command. Specific terms can be retrieved using the FIND command or a combination of FINDs using the Boolean operators, AND, OR, and ANDNOT. Ranges of numeric data can be searched using specific commands such as FIND X TO Y.

Depending on the type of data field, indexing is full field (single term), phrase (multiple terms), free text (word by word), or numeric (real number or integer). Numeric fields sometimes incorporate the capability to index alphabetical data, such as imprecise dates, which may be followed by a "?" or a "C" for circa.

INSTITUTIONAL DATA BASES

The Natural Sciences and Humanities Data Dictionaries each contain approximately 600 data fields or categories. These were compiled from the results of seven natural science and four humanities task forces, from PARIS users working groups, and from client museums' existing information standards. The task forces were made up of specialists from museums and universities across Canada, brought together to decide on information standards for their particular discipline.

Institutional data bases are created to meet the requirements of each client museum, and may contain one or more disciplines. Each data base consists of a number of data fields chosen from the Natural Sciences or Humanities Data Dictionaries. The Natural Sciences Data Dictionary includes fields for taxonomic, collection, specimen description, treatment, cataloguing, dating, habitat, geographic, publication, loan, and exhibition data. The Humanities Data Dictionary includes fields for artist, materials, object description, and conservation. Definitions, standards for data entry, and information about data field indexing are provided. Museums generally choose up to 200 data fields to allow for flexibility and future expansion but currently enter data into a subset of less than 40 fields per record.

Data are entered in several ways. The PARIS module, OLIVE, allows data to be entered and edited on-line. Three rapid data entry systems have been developed to allow entry of data into files that are transferred weekly to PARIS. Data may also be entered in Microtext format on micro-computers and transmitted weekly. Data editing using a micro-computer is currently being tested at user museums. In every case, data which are entered or edited go into a queue file and are updated weekly into the data base. The user can access data in the queue file, record by record, for proofreading or as a security check prior to each update.

A user can format the data to make simple reports on-line, using a terminal's screen display or a slave printer. Complex reports are designed by the user, a CHIN museum consultant, and a CHIN project leader. These reports are programmed to format the data according to the user's specifications, and can be printed either at CHIN or on-line at the user's terminal. Reports listing the frequency of unique entries in a field, worksheets, catalogue cards or sheets, and reports with data in columns are commonly requested.

NATIONAL DATA BASES

CHIN's mandate to create a national inventory is fulfilled through the National Data Bases, one for humanities and one for natural sciences. Any participating institution can access the National Data Bases, which act as an index to all the collections.

A set of less than 50 non-confidential, key retrieval fields were selected as National Data Base fields after consultation with client museums. These fields are a subset of the data fields in the records of the institutional data bases. Records of a confidential nature may be flagged by users so that they do not appear in the National Data Base. Ordinarily, the National Data Base is updated during the weekly update of each institutional data base.

The Humanities National Data Base is to be completely loaded during 1985–1986 with the data from 36 museums. Loading of the Natural Sciences National Data Base will start when loading of the Humanities National Data Base is complete. There are about 18 natural science departments from nine institutions across Canada that will provide data from almost 700 000 specimen records.

Members of the public or non-CHIN museums can access the National Data Bases through CHIN or the nearest CHIN client museum, which will make the search for them. In the future, the National Data Bases may be made available to additional museums.

REFERENCE DATA BASES

A series of reference files are available on-line to any CHIN users. These include the following:

1) PARIS User Guide
2) PARIS Training Data Base
3) Humanities Data Dictionary
4) Natural Sciences Data Dictionary
5) Repository of Stolen Artifacts (ROSA)—Interpol
6) National Museums Library Serials (future)
7) Internationally Travelling Exhibits—ICOM (future)

8) Artists in Canada—National Gallery of Canada (future)
9) Conservation Bibliography Data Base (future)
10) Conservation Materials Data Base (future)
11) Data Base of Museum Data Bases—Ontario Museum Association (proposed)
12) Data Base of Computer Applications—Ontario Museum Association (proposed)

The Status of the Network

The natural science disciplines represented on the PARIS system are botany, earth sciences, herpetology, ichthyology, invertebrate zoology, mammalogy, ornithology, palaeontology, and zooarchaeology. The humanities disciplines are fine and decorative arts, ethnology, archaeological specimens and sites, and history.

Over 200 individuals from both natural sciences and humanities have been trained in the five-day PARIS Introductory Training Course. These people have subsequently trained colleagues in their own institutions to use the system.

Since 1982, 2.3 million records have been converted to, or entered on, the PARIS system (natural sciences and humanities combined). In addition, there have been 4.9 million changes to these records performed by users and at CHIN through batch mode. This indicates the dynamic nature of modern museum documentation, and the continuing effort of users to standardize the format and content of data fields. Standardization is a major concern because it is necessary not only for the creation of formatted reports, but, more importantly, for effective information sharing.

A Natural Sciences Working Group of PARIS users has been formed to work on standards and other PARIS issues related to natural sciences. The Working Group meets annually at a PARIS User Representatives meeting in Ottawa, and corresponds by mail over the remainder of the year; Ottawa area users meet monthly. So far, discussions have centred on standardization of data field structure, data format, rules for entry, and the list of fields for the Natural Sciences National Data Base. In future, data field content and authority lists or key word lists will be under discussion. Working Groups for other disciplines are also active.

The Envoy 100 electronic messaging service has been implemented to allow PARIS users across the country to keep current in issues raised by the Working Groups and to receive announcements from CHIN about system changes or enhancements.

Conclusion

The PARIS system has proved to be a viable and effective tool for collections management in natural science and humanities collections. As users become more familiar with automated documentation, and as the backlog of data entry and data editing slowly disappears, the scope of PARIS will encompass new and innovative techniques impossible to envisage using multiple paper files.

The Natural Sciences National Data Base will provide a new tool for the exchange of information about collections across Canada, for comparison of specimen data in different collections, and for preliminary ecological and distributional studies.

The Canadian Heritage Information Network has become an international leader in the field of museum documentation and collections management. Museum representatives from many different countries in Africa, South America, and Europe, as well as Australia and the United States, are looking at PARIS as a model for the development or enhancement of their own automated systems. Canada is the first to have developed an automated country-wide network of museums.

Acknowledgements

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Appendix

Information packages and Data Dictionaries are available in English and French from:

Museum Services
Canadian Heritage Information Network
National Museums of Canada
365 Laurier Avenue West, 12th floor
Ottawa, Ontario, Canada K1A 0M8
(613) 992-3333

The PARIS Natural Sciences Working Group can be contacted through the co-ordinator,

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(613) 998-9262

RECORDS MANAGEMENT IN THE DEPARTMENT OF ICHTHYOLOGY AND HERPETOLOGY, ROYAL ONTARIO MUSEUM

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ABSTRACT—The computer registration of records in the Department of Ichthyology and Herpetology, ROM, including a summary of the methods prior to computerization in 1973, is reviewed. The amount and kind of data input, procedures for editing, and the outputs (cards, labels, and tables of data) are discussed with emphasis on the Ichthyology and Herpetology Canadian Heritage Information Network (CHIN) database.

Introduction

The Department of Ichthyology and Herpetology, Royal Ontario Museum, accumulates and maintains alcohol preserved whole specimens, dry skeletons, and glycerine preserved cleared and stained fishes, amphibians, and reptiles. The specimens and their associated data are of use to researchers in museums, universities, governments, and consulting agencies investigating such aspects as the variation and relationships among, and the distribution, evolutionary history, biology, and ecology of these organisms. The information about specimens can be classified into various categories, such as taxonomy (e.g., family, genus, species), catalogue data (catalogue and accession numbers, etc.), specimen data (quantity, lengths, sex, etc.), locality (where they were captured), capture data (by whom, when, and how they were caught), and ecology (the nature of the habitat in which they lived). The following discussion outlines the evolution of fish records management in the department from before 1950 to the present.

The Nature of Records Kept

Locality, habitat, and capture data for fishes are recorded on field record forms for each collecting site. Each such site usually yields several different fish species. For example, of a total of 246 sites sampled in Ontario and Quebec, the number of species lot records per site ranged from 1 to 27 (mean = 6.7). Rotenone collections from the Chagos Archipelago in the Indian Ocean were much more diverse, yielding up to a maximum of 102 species (mean = 43) per collecting site. Specimens from a collecting trip, usually consisting of several collections of mixed species preserved in formalin, are brought back to the ROM where they are accessioned. A unique (accession) number is assigned to each shipment of specimens, which might be either a single specimen or all the material collected on one field trip. For example, the over 31 000 specimens brought back from the Chagos expedition were assigned one accession number. Basic information for each accession is recorded in a ledger book and includes such data as the date received, a general description of material, the purpose of making the collection, a brief locality description, the date of collection, and the donor or collector, often with an address or institutional name. Some time after accessioning, the collections are sorted and identified to species if possible. The resulting species lots, usually consisting of several individuals each, are treated as separate records or documents, each of which can be assigned a unique catalogue number. (However, see below for a discussion of uncatalogued material.) All field record forms and species identification lists for each site are accumulated in letter-size files presently occupying 13 file drawers. The information in these files becomes the raw data used to create records.

After the early 1950s, topographic maps were often taken on collecting trips in order to mark on them the precise location of capture, and to note latitude and longitude on the field sheet. As awareness increased about environmental influences on cold-blooded vertebrates there was a gradual shift towards recording more locality and ecological data.

Manual Cataloguing Procedures

Prior to 1973, catalogue number, genus, species, locality, date of collection, and collector were recorded in a ledger in numerical order of catalogue number for each species lot. This species lot information was also handwritten on a 3 × 5 inch taxonomic file card and on the bottle label.

Before 1980, each file card corresponding to one species lot was filed and the catalogued lots were shelved

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systematically by a group number, and alphabetically by family, genus, and species. After 1980, the collection was reorganized to conform to more current taxonomic ideas, and family numbers replaced the 65 group numbers. The department compiled a family numbers list in 1980, in which 439 family names are recognized. It includes 713 synonyms. Family numbers rank the valid families of fishes in order of their primitiveness: lampreys, hagfishes, and sharks first; gobies, flatfishes, and puffers last. The card file was reorganized alphabetically by family, genus, and species. Within a species the records were organized on a geographic basis and tab cards in the card file (70 drawers at present for fishes) assisted in locating collections from specific counties or districts in Ontario, states in the United States, or other countries.

Non-catalogued Material

As a result of limited collection storage space, by the late 1950s, the department began making rigorous selection of specimens of the more common species. Species lots are not catalogued if the same species from the same locality is already well represented in the collection. For these decisions, the department defines a locality unit as: 1) a county or district of Ontario; 2) a major drainage area; or 3) an island group of an ocean or sea. Collections preferred for cataloguing consist of a good series of specimens (greater than 10 and preferably 35), including a good sample of sexually mature individuals. Collection holdings are checked prior to a field trip and an effort is made to release, alive, easily identified species with good representation in the collection. Specimens not catalogued can be disposed of in a number of ways. They can be donated to other institutions; kept in a standing exchange collection; kept in bulk storage in the same container as all other species with which they were captured; or, discarded if not enough justification exists for keeping them. (See "Computerization of Non-catalogued Material" below for a discussion of how uncatalogued specimen information is recorded.)

Computerization

INTRODUCTION

A computer database was created in 1973 to help in organizing the growing amount of information on fishes so that it could be more easily searched, reorganized, and printed in various formats, to improve the efficiency of cataloguing, and to better inform users about the contents of the collection. Once the information was entered on the database, the existence of various computer printouts made it unnecessary to handwrite or type the same information in the ledger, on the file card, on the bottle label, or in summaries requested by workers wishing to borrow our material.

Computer record management was initially carried out in-house with a specially designed system employing a PDP-8 stand-alone computer at the ROM. A later generation involved a Univac BC-7 computer which carried out both collection and business functions. In August 1983, following a 17-month period without access to any computer, the department acquired the means for building a new database within the Canadian Heritage Information Network (CHIN) of the National Museums of Canada. At this time the herpetology discipline was included in a joint database. Using a Cybernex "dumb" terminal interacting with CHIN's mainframe computer, staff can create, modify, search, and display or print records without the need for an intermediary computer operator.

ENTRY

In-house—Each record or catalogued lot in the in-house database consisted of a maximum of 40 data fields with a maximum of 512 and later 625 characters (bytes) per record. Four fields designated for the input of meristic characters of the specimens were rarely used. One of these, rays, was used to dump information which could not fit into the limited space of other fields. For example, a range of dates of capture such as 29 Nov–1 Dec could not fit into one two-character day and one three-character month field. A data dictionary was written (and continually updated) to standardize syntax and vocabulary.

The process of entering data started with the completion of mimeographed input sheets from labels, field record forms, or correspondence received with the specimens. After approximately 200 sheets were prepared they went to a separate department, Computer Services, where they were input by a clerk.

Because much of the information about collections was common to many species lots, a copying program was written to save input time. The common information (locality, ecological, capture, and some cataloguing data) usually consisted of about 25 data fields which were input once into a "skeleton" record. The information in a skeleton record closely corresponded to the information on a field record form. Once the skeleton file of common information was set up, each taxonomic unit was prepared in such a way that the computer automatically completed all the repetitive information. In this way only about eight fields unique to each record needed to be entered.

CHIN—The department has selected about 200 data fields out of a possible 667 for the Ichthyology and Herpetology CHIN database. Of these, about 88 are used with varying frequency (see Appendix). A new data dictionary has been written. Some syntax has also been more precisely defined. For example, names are entered in the form

LASTNAME, I. and dates in the form YYYYMMDD. The data dictionary gives guidelines on determining terms for drainages, country, county, etc.

Entry on the CHIN system takes two forms at present. The first is on-line with the mainframe computer. Records of up to 10 000 characters and 200 fields can be created by simple commands such as MAKE (creates a space for and assigns a unique PARIS number to a new record) and PROMPT (field, which commands the computer to prompt for information in the specified data field). The user enters OLIVE, CHIN's editing software, to make corrections or create new records. Entry can be directly from the raw data making it more efficient than the former in-house systems by omitting the need for the mimeograph input sheet. Alternatively, microcomputers are now being used to accumulate records which are then batched to the CHIN database.

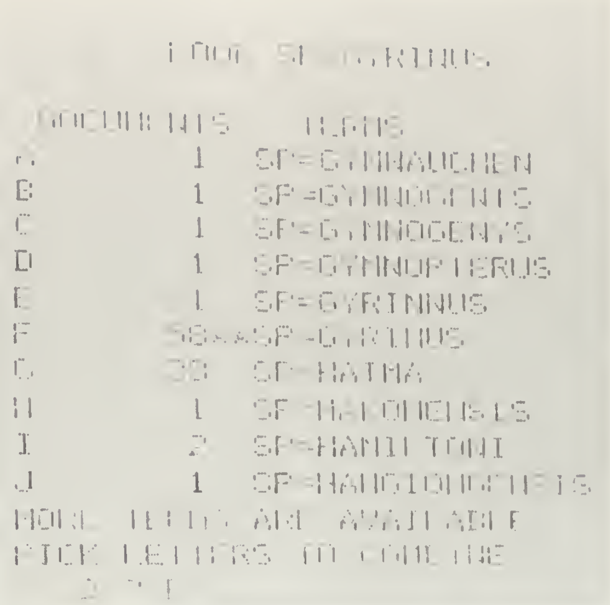
COMPUTERIZATION OF NON-CATALOGUED MATERIAL

Frequently all species lots from field trips are now entered on computer even though it is known that some of them will not receive a catalogue number. The computer can then assist with making decisions on specimen disposition (see "Non-catalogued Material" above for guidelines in selection). If all the species captured from each site are entered, the database can also give a more complete picture of species distribution, and it can become a more useful source of information in ecologically related studies such as those of population status, fish community structure, species associations, and correlations of fish species with environmental characteristics. Specimens released in the field are entered as records on the computer if their identification is certain.

EDITING

In-house—Printouts of all the information from the in-house minicomputers were checked by comparing with the handwritten mimeographs. The corrected printouts were sent back to Computer Services for correction. Errors found from day to day were accumulated on a handwritten list for later correction.

CHIN—After inputting, the record is checked for errors on the terminal by the inputter. Errors in spelling in the database can be spotted quickly by displaying or printing alphabetical lists which summarize the frequency with which a term occurs in a specified field (LOOK or EXPAND command, see Fig. 1). Corrections to the data can be made immediately when errors are discovered while searching onscreen or when spotted on various printouts. A validation process in Ottawa ensures that numeric fields contain only numbers, and that date fields contain only eight digits. Since all original labels, notes taken in the field, identification sheets, and correspondence are kept, it is always possible, though time-consuming, to go back and check and, if necessary, modify or recreate the record.



```
        LOOK SP=GYRINUS

 DOCUMENTS    TERMS
A        1    SP=GYMNAUCHEN
B        1    SP=GYMNOGENIS
C        1    SP=GYMNOGENYS
D        1    SP=GYMNOPTERUS
E        1    SP=GYRINNUS
F       58    SP=GYRINUS
G       30    SP=HATMA
H        1    SP=[illegible]
I        2    SP=HAMILTONI
J        1    SP=[illegible]
MORE TERMS ARE AVAILABLE
PICK LETTERS TO CONTINUE
   ? F
```

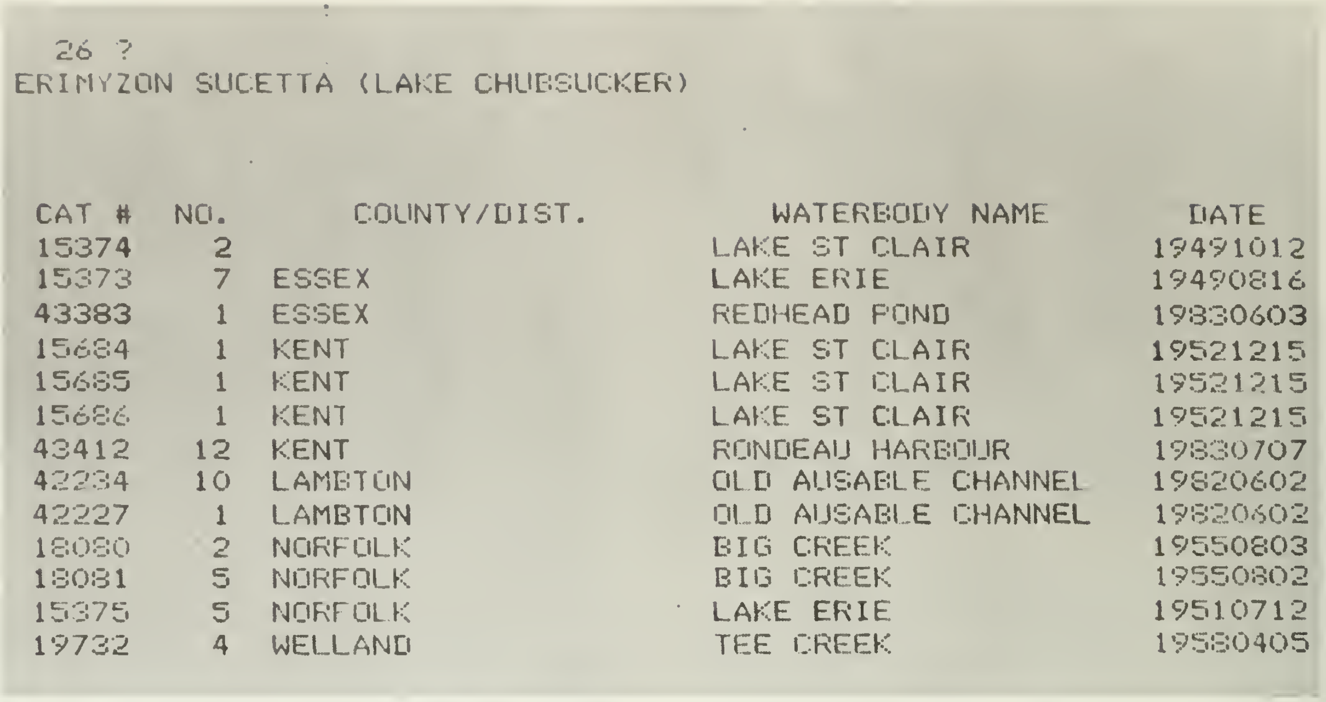
Fig. 1. An example of the use of the LOOK command. The search term is SPECIES = GYRINUS, the species name for tadpole madtom. The computer can list up to 19 alphabetically-adjacent terms from which a document set can be created. Note the misspellings, GYRINNUS and GYMNOGENIS, which should be respectively, GYRINUS and GYMNOGENYS.

Global changes are easily performed on a defined document set on-line by the user. Global changes involving more than a few hundred records are more efficiently performed by the staff at CHIN.

OUTPUTS

In-house—After editing all the information, the ROM in-house systems printed up bottle labels, file cards, and a list of records in numerical order of catalogue number with a four-line entry containing data similar to that in the handwritten catalogue books. Printouts (Escort Data Listings) of selected records and selected fields could also be produced.

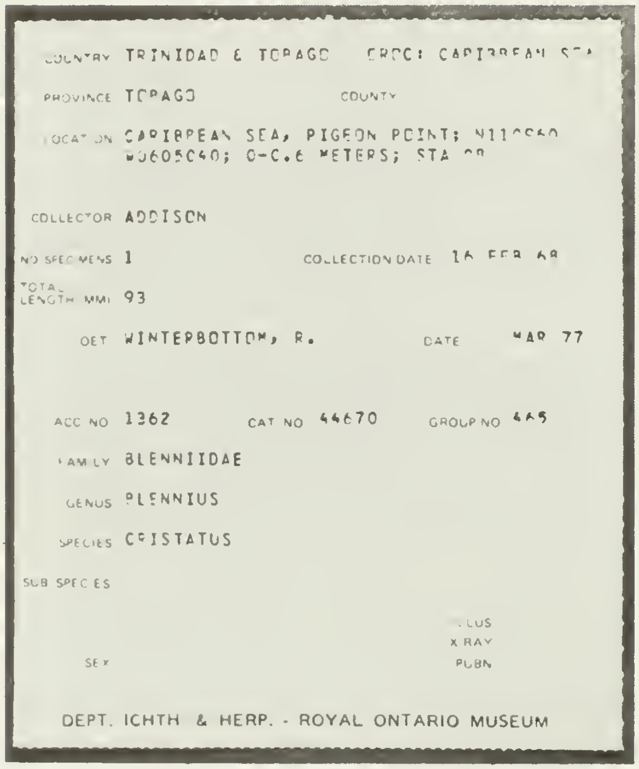
CHIN—All or any number of fields of a record in the CHIN database can be printed using the DISPLAY (field 1, etc.) command. Alternatively, tables of from 1 to 20 fields can be printed using the REPORT DISPLAY command (see Fig. 2). Printouts can be produced by ROM staff on a central microcomputer and printer on-line in Toronto to the central CHIN mainframe computer in Ottawa. Certain specially formatted reports such as file cards (Fig. 3) and bottle labels (Fig. 4) are presently printed in Ottawa and mailed to the ROM. Alternatively, data can be downloaded onto floppy discs, and edited and printed



```
  26 ?
ERIMYZON SUCETTA (LAKE CHUBSUCKER)


 CAT #   NO.      COUNTY/DIST.            WATERBODY NAME         DATE
 15374    2                          LAKE ST CLAIR             19491012
 15373    7   ESSEX                  LAKE ERIE                 19490816
 43383    1   ESSEX                  REDHEAD POND              19830603
 15684    1   KENT                   LAKE ST CLAIR             19521215
 15685    1   KENT                   LAKE ST CLAIR             19521215
 15686    1   KENT                   LAKE ST CLAIR             19521215
 43412   12   KENT                   RONDEAU HARBOUR           19830707
 42234   10   LAMBTON                OLD AUSABLE CHANNEL       19820602
 42227    1   LAMBTON                OLD AUSABLE CHANNEL       19820602
 18080    2   NORFOLK                BIG CREEK                 19550803
 18081    5   NORFOLK                BIG CREEK                 19550802
 15375    5   NORFOLK                LAKE ERIE                 19510712
 19732    4   WELLAND                TEE CREEK                 19580405
```

Fig. 2. An example of a report display or table of data which can be displayed on the screen or produced at the ROM.



COUNTRY TRINIDAD & TOBAGO   DRDC: CARIBBEAN SEA

PROVINCE TOBAGO   COUNTY

LOCATION CARIBBEAN SEA, PIGEON POINT; N11[illegible]
W0605040; 0-0.6 METERS; STA [illegible]

COLLECTOR ADDISON

NO SPECIMENS 1   COLLECTION DATE 16 FEB 69

TOTAL LENGTH (MM) 93

DET WINTERBOTTOM, R.   DATE MAR 77

ACC NO 1362   CAT NO 44670   GROUP NO 465

FAMILY BLENNIIDAE

GENUS BLENNIUS

SPECIES CRISTATUS

SUB SPECIES

ILLUS
X RAY
SEX   PUBN

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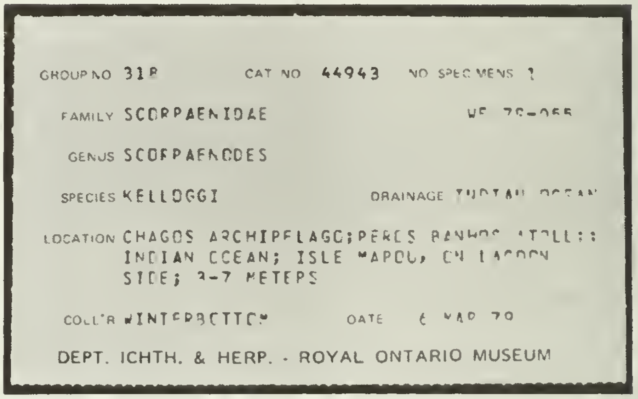
Fig. 3. A computer file card with burstings removed. The card is folded in half to fit into a 3 × 5 card cabinet.



GROUP NO 318   CAT NO 44943   NO SPECIMENS 1

FAMILY SCORPAENIDAE   WF 70-065

GENUS SCORPAENODES

SPECIES KELLOGGI   DRAINAGE INDIAN OCEAN

LOCATION CHAGOS ARCHIPELAGO; PEROS BANHOS ATOLL:
INDIAN OCEAN; ISLE MAPOU, ON LAGOON
SIDE; 3-7 METERS

COLL'R WINTERBOTTOM   DATE 6 MAR 70

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Fig. 4. A waterproof computer bottle label with burstings removed.

using a text editor such as Wordstar. A special report, "SPECIESLIST", programmed by CHIN, summarizes the species occurring in a specified document set and for each species calculates the number of lots, total number of specimens, and length range of all individuals.

Outputs for Non-catalogued Material vs Catalogued Material—Lists of documents generated by the computer can include both catalogued and uncatalogued material, unless a conditional statement excluding uncatalogued lots is made during the search. An alpha-character is inserted in the catalogue number field of uncatalogued lots (e.g., "E" for exchange) and an entry such as "GIFT TO USNM" is made in the disposition mode data field. Only species lots shelved in the main collection area receive bottle labels and only for these are file cards produced.

Discussion

A major advantage of the CHIN system has been to make data easily and quickly accessible through the use of a terminal on-line to a mainframe computer. The powerful search and retrieval capabilities of PARIS, the software package used by CHIN, opens up many opportunities for analysis of the database. Searches are very quick when compared with microcomputer speed. All but the "remarks" fields are indexed in a separate file, making possible complex searches with as many conditional statements as there are indexed fields. Even "remarks" fields can be searched (using the SCAN command) on document sets of less than 5000 records for one or any combination of characters in any specified position in the field. Many numeric fields are range searchable so that the entire database can be searched for ranges of dates, depths, distances, latitudes, longitudes, and specimen lengths.

As a result of being on-line at the same time as up to 79 other databases, response time slows down the rate of entry and editing of records. The response time has been greatly improved recently with the installation of a more powerful mainframe computer at CHIN and with an increase in baud rate from 300 to 1200. There are two ways to improve response time. Firstly, new records and changes to old records can be keyed in without waiting for the screen to respond. Although staff members in the department use this technique routinely, other users may feel uncomfortable in not being able to see the sequence of commands and responses on the display terminal. Secondly, response time can be greatly reduced with the use of microcomputers. Much progress has been made at the ROM recently in the use of microcomputers for handling the entry and editing of records. A major portion of the records in the database have been created on microcomputers, and the process of downloading records from CHIN, so that they can be edited on microcomputers, is now feasible.

Data entry and modification is usually performed by the person who has compiled the information from the raw data. This has eliminated two intermediary steps: 1) the entering of data from a mimeograph sheet by a computer operator, usually untrained in ichthyology; 2) the checking for typographical errors on computer printouts. Editing can be done while searching, retrieving, and displaying parts of the database. This is a significant improvement which will "clean" the data much more quickly.

The number of data fields used has increased from 40 on the in-house database to about 88 on the CHIN database. Some of this increase results from splitting one field into two or more fields. For example, location is now entered in eight different fields on the CHIN database: waterbody name, township, locality description, locality remarks, stop latitude, stop latitude direction, stop longitude, and stop longitude direction. There are also several new fields: cataloguer, cataloguing date, identifier, identification date, accession date, distance from shore, stream width, stream cover, map reference, three more drainage fields, etc.

In less than two years, four permanent and several part-time staff built a database of 20 000 records, each spending from 25 to 50% of their time entering data. The keying-in process usually follows the cataloguing process (counting and measuring specimens, looking up drainage and political boundaries on maps, calculating latitude and longitude, and assigning catalogue numbers). However, frequently one or more of the steps is performed during the keying-in process, which increases the time needed for entering data (i.e., up to 20 or more minutes). If all the information is readily at hand, a 50-field record should take approximately 5 minutes to input on-line.

Computer and communications costs for this system are substantial. Recently a cost recovery proposal by the National Museums Corporation indicated a cost per record of $0.50 per year for storage and maintenance, as well as a cost of $10.00 per hour for connect time. Assuming a connect time of 4 hours per day, 5 days a week for 50 weeks for a growing database of 25 000 records, costs are $12 500 for storage and maintenance plus $9600 for connect time for a total of $22 100 per year. These costs are shouldered by CHIN which is dependent on federal government funding. Thus a federal policy change could alter access to the computer and the Ichthyology and Herpetology database. In returning for providing such an expensive service, CHIN gains access to our database, part of which will be transferred to a Natural Sciences National Data Base, which is in the process of being set up now.

The computer's main function in the department has been to produce bottle labels, file cards, and a catalogue listing. Printouts generated at the ROM can be done quickly—usually on the day requested. On the other hand, the small staff at CHIN, who should be commended for their helpfulness under the circumstances, service 79 other databases and there is usually a waiting period, the length of which depends on the priority of the job. As a result, bottles awaiting labels accumulate in a separate area of the collection where they are more difficult to access than those shelved systematically. Recently, as a result of extra cataloguing assistance, this has become a problem because collections have become increasingly difficult to locate among the estimated 2000 bottles accumulated in the "bottles awaiting labels" section. The situation will be improved when the ROM acquires a laser printer and the programming necessary to generate cards and labels on site.

At present most of the effort is being devoted to data input and verification. As the database grows, it will be used increasingly for producing outputs such as the following: collection summary lists for researchers wishing to borrow our material; collecting reports; and lists for studies of fish community structure, distribution, population status, correlations of fish species with environmental characteristics, and species associations.

Acknowledgements

The author is grateful to the following people for making useful comments on the manuscript or for providing information: E. J. Crossman, Janet Waddington, Ian Sutherland, Gary Friedman, Marili Moore, Tosh Yamamoto, and Margaret Rouse.

Appendix: List of ichthyology data fields for the in-house minicomputer database (1972—1983), and the Canadian Heritage Information Network (CHIN) database (1983 onwards)

TAXONOMIC FIELDS

In-house	CHIN
Group number	Family number*
Family	Family*
Genus	Genus
Species	Species
Subspecies	Subspecies
	Synonyms
	Taxonomic remarks
	Identifier
	Identification date
	Identification remarks
	Hybrid name

CATALOGUING FIELDS

In-house	CHIN
Catalogue number	Catalogue number (alpha-numeric)*
	Integer catalogue number (range-searchable)
	Cataloguer*
	Cataloguing date*
	Cataloguer's remarks
Accession number	Accession number*
	Accession date*
Container/box number	Container/box number
Validity	(No equivalent)
	Shelf number
	Disposition mode
	Flag
	Other catalogue number
	Previous catalogue number
	Mode of acquisition
	Specimen slide number
	Locality photo
	X-ray number

SPECIMEN DATA FIELDS

In-house	CHIN
Number of specimens	Number of specimens*
Total/standard length range	Minimum total length
	Maximum total length
	Minimum standard length
	Maximum standard length
Condition	Age
	Sex
	Specimen nature
	Specimen remarks
Type status	Type status
	Weight
Vertebrae	
Rays	
Lateral Line Scales	

LOCALITY FIELDS

In-house	CHIN
Country	Country
Province	Province
County	County
Drainage	Ocean drainage*
	Primary drainage
	Secondary drainage
	Tertiary drainage
	Watershed code (for Ontario records)
Latitude	Start latitude
	Start latitude direction
Longitude	Start longitude
	Start longitude direction
	Stop latitude
	Stop latitude direction
	Stop longitude
	Stop longitude direction

Location	Waterbody name*
	Township
	Locality description
	Locality remarks
	Cruise station
Cruise number	Cruise number
	Vessel name
	Map reference

CAPTURE FIELDS

In-house	CHIN
Collector(s)	Collector(s)*
Day	Capture date*
Month	
Year	
Hours	Capture time
	Duration
Capture method	Capture method
	Capture remarks
	Mesh size
	Gear size
Field number	Field number

*Must have entry (mandatory field)

ECOLOGICAL FIELDS

In-house	CHIN
Waterbody type	Waterbody type*
Waterbody description	(No equivalent)
Depth of capture	Minimum capture depth
	Maximum capture depth
	Units of depth
	Minimum distance from shore
	Maximum distance from shore
	Stream width
	Units of distance
Salinity	Salinity*
Water quality	Water quality
Water/air temperature	Water temperature
	Air temperature
Total water depth	(No equivalent)
Current	Current
Aquatic vegetation	Aquatic vegetation
Bottom description	Bottom description
	Stream cover
	Sessile organisms

STANDARDIZATION AND INDEXING OF TERMINOLOGY FOR VERTEBRATE FOSSILS ON THE CHIN PARIS CATALOGUING SYSTEM

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ABSTRACT—In order that a computerized cataloguing data base be useful to several institutions, standardization of terminology is necessary. The Department of Vertebrate Palaeontology, Royal Ontario Museum, has devised a system of terminology for fossil bones. In describing each fossil, one or more of nine primary descriptors are used followed by a string of modifiers. These terms indicate the position within the skeleton, age, the completeness of the bone, whether the bone is pathological or a reproduction, and the quantity of bones present. Although we have arrived at a standard and ordered set of bone and tooth terminology, the system can be modified to meet specific needs and preferences without disrupting its overall usefulness.

Introduction

In the spring of 1983, the Department of Vertebrate Palaeontology, Royal Ontario Museum, obtained a link-up with the CHIN (Canadian Heritage Information Network) PARIS (Pictorial and Artifact Retrieval and Information System) computer cataloguing system. After the first few hundred records were entered it became obvious that if the system was to be useful, standardization would be essential. Since we were the first department of fossil vertebrates to use the system, we attempted a preliminary standardization.

Most types of information have a source for standardization, such as dictionaries, atlases, and the international commissions on zoological nomenclature (ICZN) and stratigraphy (ICSN). However, the lack of standardization for bone terminology was noted as early as 1880 (see Günther, 1880). The situation today has improved; various attempts to standardize terms have been made for each class of vertebrates (e.g., Gregory, 1933, for fish; Romer and Parsons, 1977, for amphibians; Romer, 1956, for reptiles; Howard, 1929, for birds; Flower, 1885, for mammals).

Mammalian bone terminology is complicated because physicians, veterinarians, and comparative anatomists often use different names for the same bones. Generally, English-speaking palaeontologists favour the terminology of comparative anatomists as presented in Romer and Parsons (1977). Because basic standardization of terms is unlikely owing to individual preferences, computer standardization is more difficult. An added problem is that palaeontologists frequently deal with fragments. This means that we also need standard terms to describe incomplete bones.

This paper outlines the system we have developed and summarizes the more important concepts involved in computer use and standardization. We expect some of the details to change with refinement. However, we think that this system renders efficient searching possible, while still being flexible enough to allow for individual terminological and cataloguing preferences.

CHIN and PARIS

For information on the history of CHIN and PARIS see Rogers (1984). Standardization manuals for all fields for both the humanities and natural sciences data bases have been published (Delroy et al., 1985; Delroy, Jewett, and Bellamy, 1985). The PARIS system is described in detail by Cox (this volume). However, a few relevant points need to be mentioned here.

Although created primarily for cataloguing and collections management, PARIS is intended to assist research. As well, this system has the major goal of setting up a National Data Base for both the humanities and natural sciences. Thus any institution using the system, or any interested member of the public, could access a copy of any data base on the system for research purposes. CHIN controls the copying, while the selected fields have been agreed upon by most parties involved. Because several researchers may use the system, the need for standardization is obvious.

The PARIS system often provides more than one way of performing a certain task. Three important terms used in searching for records are the following Boolean logic operators:

AND—both one and the other
OR—one or the other or both
ANDNOT—one and not the other

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Complex searches involving different fields, as well as different terms within fields, are possible by combining these operators. The only warning necessary is that these three operators, as well as other machine language terms (END, ALL, AT, MORE, TO), should be avoided where possible in bone descriptions. Thus such terms as DISTAL END, should be changed to DISTAL PART.

The PARIS system index is separate from the main data file. For fields that are phrase-indexed, the computer automatically puts each phrase or word into an alphabetical index when the record is created. When searching for a word or phrase, the computer searches the index and not the main data file; this speeds up the process considerably. A semicolon is used to separate each word or phrase to be indexed separately. We also prefer to add a space after the semicolon for ease of reading, although this is not necessary.

Not all fields need to be phrase-indexed. Of the approximately 75 fields into which we commonly enter data, only a few are so indexed, because many fields usually have only one word or number entered in them (e.g., those fields handling taxonomic or numerical data). Therefore, phrase-indexing is ideal for those fields in which a string of data is entered and any portion of that string may be required separately. One such field is the specimen description (SPENA) field.

SPENA

SPENA is an acronym for *spe*cimen *na*ture. We use this field for a complete description of the fossil. The order in which information is written for any particular description is not of great importance since each word or phrase is indexed separately. However, we prefer the following order: bone name; completeness; age (e.g., juvenile); left or right; cast or original; number of bones; pathology. The first term is the most general; subsequent terms are increasingly more specific, modifying or further defining the previous term(s). This allows one to search at any level, providing the terms are known. The most general terms are inflexible and few in number, allowing rapid basic access. The more specific terms may vary according to preferences for bone names. (All will be alphabetically indexed by the computer.) We have tried to design the system so that each description provides a clear idea of the appearance of each specimen.

Although there are separate fields for some of these types of data (e.g., age, quantity), we prefer to put all this information into one field. As long as the field is phrase-indexed, it is accessible, and no time is wasted searching different fields for parts of the bone description. Moreover, requiring only one specimen description field to be printed for each specimen facilitates label printing.

In the description, a bone is assumed to be adult and original unless stated as JUVENILE or CAST. To facilitate searches, the terms COMPLETE and INCOMPLETE are included where appropriate. If the term JUVENILE is present for mammalian bones, it is assumed that no epiphyses are present, unless otherwise stated.

The term PARTIAL is used when one part of a multi-part object is present, such as a skull, mandible, pelvis, or turtle shell. INCOMPLETE is used for a single element that is missing a portion. If the orientation of the incomplete portion is known, then PROXIMAL PART, DISTAL PART, ANTERIOR PART, etc., may be used. If the proximal part of a bone is itself broken, then both terms PROXIMAL PART and INCOMPLETE may be used together.

Auxilliary data can be included in a remarks field which is not phrase-indexed. This helps keep the specimen description standardized. Adding an ampersand (&) at the end of a description informs the user that more information is present in the associated remarks field.

Catalogue Numbers (CN)

We consider that all bones from an individual should be given the same catalogue number. However the option to enter separate records for each bone is left open to the cataloguer. Normally each record would receive its own specimen label. However, in cases where many bones are catalogued under one catalogue number and each bone should have its own label, many records can be created, each with the same catalogue number. This would be appropriate for an associated group of large bones or a large number of associated bones where one specimen label could not give a complete description of all bones. If the specimen is an associated group of small bones, one label may suffice and hence one record.

Major bones or fragments, even if all other data are the same, should be given their own catalogue number in order that researchers may refer to each bone separately. It is expedient to batch identical minor bones together under one catalogue number as long as all other data are the same. We define minor bones as ribs, phalanges, and fragments that are not usually studied individually. We also batch horse teeth, alligator teeth, and osteoderms because we have so many from a few localities.

Casts should be given the same catalogue number as the original, if the original is in the same collection. They should be entered as separate records since their descriptions will be different.

If the catalogue number is suffixed with "A", "B", "C", etc., representing a series of identical bones (e.g., left humeri), each should be given its own record. These obviously represent different individuals, and if given their own record, their alpha-numeric catalogue number can be treated as unique (examples 1 and 2 below). There are two exceptions: 1) if "A" and "B" signify shaft and epiphysis of one bone, assign one record (example 3) and create the specimen description as suggested in the Bone section; 2) if "A" and "B" are part and counterpart of the same individual, assign one record (example 3).

Example 1: (CN) 19475 A
Example 2: (CN) 19475 C
Example 3: (CN) 28043 A, B

ROM System

Nine primary descriptors are used, followed by modifiers. All specimens should be identified under at least one of these nine headings: SKELETON, SKULL, MANDIBLE, TOOTH, OSTEODERM, PLASTRON, CARAPACE, BONE, and OTHER.

When using the term PARTIAL, we prefer not to enter a semicolon between it and the primary descriptor. This creates a number of additional cognate primary descriptors such as SKELETON PARTIAL, SKULL PARTIAL, and MANDIBLE PARTIAL. These aid in searching for complete specimens, since only they will be indexed under the single term SKELETON, SKULL, or MANDIBLE.

If information is questionable, add a space and a question mark after the term. Once again, the space is not necessary but we prefer it.

Representative examples of each category are included below. A variety of examples is given covering the main possibilities.

1) Skeleton: For any articulated or associated portion of a skeleton:

e.g., SKELETON PARTIAL
SKELETON PARTIAL; MANUS
SKELETON PARTIAL; PART & COUNTERPART

The field labelled SPREM is used for specimen remarks, and that labelled SPEAA to note associated specimens. An ampersand at the end of a SPENA description reminds the researcher that more information may be entered in either SPREM or SPEAA or both. For a fish, the following description is possible:

e.g., (SPENA): SKELETON PARTIAL; ANTERIOR PART; &
(SPREM): NO TAIL; 14 × 8 × 4 CM

For a mammal the following description is possible:

e.g., (SPENA): SKELETON PARTIAL; TIBIA; LEFT; &
(SPEAA): FIBULA 3215; FEMUR 3216; PES 3217–3222

The numbers in SPEAA are understood to be the computer assigned record numbers since all these bones would have the same catalogue number.

2) Skull: For any part of a skull, including antlers, horn cores, bullae, hyoids, etc.:

e.g., SKULL; COMPLETE
SKULL PARTIAL
SKULL PARTIAL; PARIETAL
SKULL PARTIAL; GLENOID, MASTOID; LEFT
SKULL PARTIAL; PARIETAL ?; INCOMPLETE
SKULL PARTIAL; ANTLER; INCOMPLETE
SKULL PARTIAL, AUDITORY BULLA
SKULL PARTIAL; PHARYNGEAL PLATE

A hyoid bone could be expressed as

SKULL PARTIAL; HYOID

For a partial skull *with* a hyoid, it is suggested that the partial skull be clarified in some way:

e.g., SKULL PARTIAL; ANTERIOR PART; HYOID
SKULL PARTIAL; INCOMPLETE; HYOID

For a complete skull with an associated hyoid use:

SKULL; COMPLETE; HYOID

3) Mandible: We define a mandible as both halves, a partial mandible as one half (right or left), an incomplete mandible as both halves with parts missing, and an incomplete partial mandible as one half with parts missing. For non-mammals with partial mandibles that are made up of a number of bones, the specific bones present should be specified.

(Reptile) e.g., MANDIBLE PARTIAL; DENTARY; INCOMPLETE; LEFT
(Mammal) e.g., MANDIBLE PARTIAL; INCOMPLETE; LEFT
MANDIBLE; INCOMPLETE; EDENTULOUS

4) Tooth: Because the PARIS system does not readily handle superscripts, subscripts, or lower case letters, two alternatives are possible for labelling mammalian teeth. Both systems use the following abbreviations: I = incisor, C = canine, P = premolar, and M = molar.

a) Use U to represent upper and L to represent lower. Hence UM3, LP1-4. Deciduous teeth can be represented by an upper case D, e.g., DLP3.

b) Use a slash, as illustrated by Thewissen et al. (1983). Hence upper M1 becomes M1/; lower M1 becomes M/1.

We prefer the first alternative.

Use a hyphen to designate inclusive teeth of each type only, e.g., write UP2-4; UM1-3 instead of UP2-M3.

We have also found that when using TOOTH in conjunction with SKULL or MANDIBLE, the cognate terms TOOTH COMPLETE and TOOTH INCOMPLETE help avoid repetition of separately indexed completeness terms.

e.g., TOOTH; DUP4; COMPLETE; LEFT
(i.e., a complete deciduous upper left fourth premolar)
TOOTH; LP; INCOMPLETE
(i.e., an incomplete lower premolar)
MANDIBLE PARTIAL; TOOTH COMPLETE; LI1-3; LP2-4; LM1-3; RIGHT
(i.e., a right mandible with incisors 1–3, premo-

lars 2–4, and molars 1–3)
MANDIBLE; INCOMPLETE; TOOTH COMPLETE; LI2-3; LP2-3; LM1-3; RIGHT; LI1-2; LP3-4; LM1-3; LEFT; TOOTH INCOMPLETE; LI1; LP4; RIGHT; LI3; LP2; LEFT (i.e., a broken mandible, both halves present, with right first incisor, right fourth premolar, left third incisor, and left second premolar incomplete; all other teeth listed are complete)

We recognize that some institutions may wish to list all teeth separately to facilitate searches for particular teeth. We prefer to group list to save space on specimen labels. As well, the LOOK command on CHIN allows rapid access to "grouped" tooth terminology.

For five non-mammalian teeth:
e.g., TOOTH; COMPLETE; 5

For horses and others with molariform teeth (i.e., premolars that resemble molars and are difficult to separate from them) use the word "MOLARIFORM":
e.g., TOOTH; MOLARIFORM; UPPER; INCOMPLETE; LEFT; 5

This concept can be adapted to obtain the terms CANINIFORM (e.g., in some sloths) and INCISIFORM (e.g., in some fish).

5) Osteoderm: Describe type or location on body if known. For edentates use "BUCKLER", "IMBRICATING", "LIMB", "CEPHALIC", "CAUDAL".
(edentate) e.g., OSTEODERM; BUCKLER; INCOMPLETE
(turtle) e.g., OSTEODERM; SPUR; COMPLETE

Placoderm dermal plates may be included in this category.
e.g., OSTEODERM; DORSAL PLATES; ANTERIOR PART; IMPRESSION

6) Turtle shell: For turtles with unfused carapace/plastron as adults (i.e., most except box turtles) use "PLASTRON" or "CARAPACE" followed by individual element by name:
e.g., PLASTRON PARTIAL; HYPOPLASTRON; INCOMPLETE; LEFT; 3
CARAPACE PARTIAL; NUCHAL; COMPLETE

For box turtles (adults having completely fused carapace and two-lobed plastron):
e.g., CARAPACE; INCOMPLETE; 5
PLASTRON PARTIAL; ANTERIOR LOBE; INCOMPLETE

For immature box turtles (unfused carapace/plastron) catalogue as for other turtles, and add "JUVENILE":
e.g., CARAPACE PARTIAL; PERIPHERAL; INCOMPLETE; JUVENILE

7) Bone: Subheadings suggested are: vertebra, rib, hemapophysis, sternum, pelvis, manus, pes, and individual long bone names. For the mammalian atlas and axis, also use cervical I or II, as appropriate, for ease of searching.
e.g., BONE; VERTEBRA; CERVICAL II; AXIS; INCOMPLETE
BONE; VERTEBRA; CERVICAL IV; COMPLETE

Note how each of the following expresses doubt concerning a different part of the identification:
BONE; VERTEBRA; LUMBAR; III ?; INCOMPLETE (i.e., type of vertebra known, position uncertain)
BONE; VERTEBRA; LUMBAR ?; I ?; INCOMPLETE (i.e., both type and position uncertain)

For a mammalian pelvis:
e.g., BONE; PELVIS; COMPLETE
BONE; PELVIS PARTIAL; ISCHIUM; INCOMPLETE; LEFT
BONE; PELVIS PARTIAL; ACETABULUM; LEFT
BONE; PELVIS PARTIAL; INCOMPLETE; LEFT

This last example describes a pelvis with portions of at least two of the pelvic elements (ischium, ilium, pubis) present.

Figure 1 is a series of diagrams of a mammalian radius with accompanying specimen descriptions to illustrate the range of variation possible. Note that if the term JUVENILE is present, the implication is that all epiphyses are missing unless otherwise stated. Note also that DISTAL is understood for the epiphysis in examples 12 to 15. For all the following examples, except 1, 2, 6, and 8, an analogous description can be constructed for the equivalent proximal portion. Example 18 (a mammalian femur) is included to illustrate the description of a bone with more than two epiphyses.

If a bone is judged to be sub-adult and not juvenile, we suggest using the term JUVENILE for the simplicity of indexing and entering the term SUB-ADULT in a remarks field.

We suggest inserting the word "MANUS" or "PES" (as appropriate) before the specific bone name. This will assist in searching.
e.g., BONE; PES; CALCANEUM; COMPLETE; LEFT
BONE; MANUS; METACARPAL III; COMPLETE; LEFT
BONE; MANUS; DIGIT III; PHALANX TWO; COMPLETE; LEFT; CAST; 2
BONE; MANUS; METACARPAL III; PHALANX ONE; PHALANX TWO; UNGUAL; COMPLETE; LEFT

The third example above is a description of two identical phalanges without a metacarpal hence the use of the term "DIGIT" and not "METACARPAL". The first two examples describe one bone only whereas the last example describes four different bones (a metacarpal and three phalanges).

For artiodactyl cannon bones, use "DISTAL PART; INCOMPLETE" to describe lateral or medial portions of the distal part. "DISTAL PART" alone would imply both portions of the distal part:
e.g., BONE; PES; CANNON BONE; PROXIMAL PART; LEFT
BONE; MANUS; CANNON BONE; DISTAL PART; INCOMPLETE; 15

For bones of uncertain position, do the best you can!

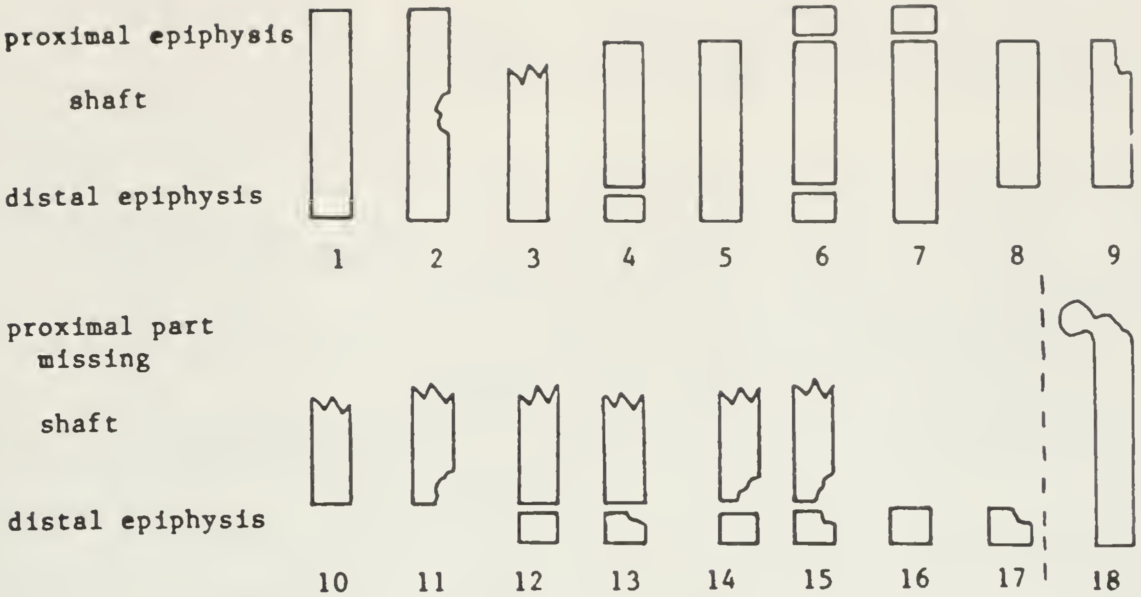

Fig. 1. Illustrated examples of SPENA using the terms JUVENILE and EPIPHYSIS.

1. BONE; RADIUS; COMPLETE; LEFT
2. BONE; RADIUS; INCOMPLETE; LEFT
3. BONE; RADIUS; DISTAL PART; LEFT
4. BONE; RADIUS; JUVENILE; LEFT; EPIPHYSIS; DISTAL
5. BONE; RADIUS; JUVENILE; LEFT; EPIPHYSIS; DISTAL; FUSED
6. BONE; RADIUS; JUVENILE; LEFT; EPIPHYSIS; PROXIMAL; DISTAL
7. BONE; RADIUS; JUVENILE; LEFT; EPIPHYSIS; DISTAL; FUSED; PROXIMAL
8. BONE; RADIUS; JUVENILE; LEFT
9. BONE; RADIUS; INCOMPLETE; JUVENILE; LEFT
10. BONE; RADIUS; DISTAL PART; JUVENILE; LEFT
11. BONE; RADIUS; DISTAL PART; INCOMPLETE; JUVENILE; LEFT
12. BONE; RADIUS; DISTAL PART; JUVENILE; LEFT; EPIPHYSIS
13. BONE; RADIUS; DISTAL PART; JUVENILE; LEFT; EPIPHYSIS; INCOMPLETE
14. BONE; RADIUS; DISTAL PART; INCOMPLETE; JUVENILE; LEFT; EPIPHYSIS
15. BONE; RADIUS; DISTAL PART; INCOMPLETE; JUVENILE; LEFT; EPIPHYSIS; INCOMPLETE
16. BONE; RADIUS; EPIPHYSIS; DISTAL; LEFT
17. BONE; RADIUS; EPIPHYSIS; DISTAL; INCOMPLETE; LEFT
18. BONE; FEMUR; JUVENILE; LEFT; EPIPHYSIS; DISTAL; PROXIMAL MEDIAL; FUSED

The insertion of the phrase "MANUS OR PES" will aid in searching. However when searching for this phrase remember to enter it in quotation marks so that the computer does not interpret the OR as a Boolean operator.

e.g., BONE; MANUS OR PES; PHALANX; UNGUAL; COMPLETE
BONE; MANUS OR PES; METAPODIAL; INCOMPLETE
BONE; METACARPAL III OR IV; INCOMPLETE; LEFT

If there is doubt concerning METAPODIAL or DIGIT assignment, use the "?" system previously illustrated for VERTEBRA.

e.g., BONE; METACARPAL; III ?; INCOMPLETE; LEFT
BONE; METACARPAL ?; III; INCOMPLETE; LEFT
BONE; METACARPAL ?; III ?; INCOMPLETE; LEFT

8) Other: Possible headings include: FISH SPINE, SCALE, TAIL BARB, ICHNITE, COPROLITE, EGG, SKIN IMPRESSION, GASTROLITH, PSEUDO FOSSIL, THIN SECTION, POLISHED SECTION, PEEL SECTION, etc.:

e.g., OTHER; FISH SPINE; PECTORAL; COMPLETE
OTHER; FISH SPINE; DORSAL FIN; COMPLETE
OTHER; FISH SPINE; NEURAL; HYPEROSTOTIC; INCOMPLETE; 9
OTHER; SCALE; COMPLETE; 2
OTHER, TAIL BARB; INCOMPLETE; 5

PATHOLOGICAL

If a bone is pathological add that word at the end of the line:

e.g., BONE; TIBIA; COMPLETE; RIGHT; PATHOLOGICAL

NOTE: there is a field "PATHOLOGICAL" (PATH), in which a descriptive entry should be inserted as well.

e.g., (PATH): EXUBERANT CALLUS ON DISTAL PART OF TIBIA

FUSION

If bones are fused together "FUSED" may be placed as follows:

e.g., BONE; VERTEBRA; CERVICAL II - IV; FUSED; COMPLETE
BONE; VERTEBRA; 3; FUSED; INCOMPLETE
CARAPACE PARTIAL; NEURAL; 2; FUSED; COMPLETE

For those bones that are normally fused, we have been using the following format:

BONE; TIBIA-FIBULA; DISTAL PART; LEFT

rather than

BONE; TIBIA; FIBULA; FUSED; DISTAL PART; LEFT

In some animals fusion is normal; commonly used names include ECTOMESOCUNEIFORM, NAVICULOCUBOID for deer pes, ENTOMESOCUNEIFORM for horse pes, and SCAPHOLUNAR for carnivore manus.

If the status of the fusion in unknown, either system may be used. We suggest that the first example below is preferable, although longer:

BONE; PES; METATARSAL II; MESOCUNEIFORM; FUSED; LEFT
BONE; PES; METATARSAL II-MESOCUNEIFORM; LEFT

Acknowledgements

I would like to thank Dr Gordon Edmund, ROM, for his ideas and encouragement throughout this project and Pamela Purves, ROM, for typing the manuscript. I would also like to thank Margaret Ballantyne and Dr James Burns of the Provincial Museum of Alberta, Edmonton (even though they may not always like the way we do things), and two anonymous reviewers for their very constructive comments and suggestions which greatly improved the manuscript.

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GEOLOGICAL COLLECTIONS MANAGEMENT AT THE NOVA SCOTIA MUSEUM

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Abstract—The collections of the Halifax Mechanics Institute, founded in 1831, were mostly geological in nature. In order to preserve these and several other collections assembled for international exhibitions, the provincial museum was established by act of legislature in 1868. Since then, it has grown from a small-quarters, one-man institution (even into the late 1930s) to today's organization of 140 full-time and over 150 part-time staff located in 23 branches throughout the province.

This paper details the historical background of the geological collections, collections management now in practice, investigations into automation, the systems study and analysis carried out, the software and hardware evaluations performed, as well as the selections made and the reasons for those choices.

Collections Background

Shortly after its founding, the Halifax Mechanics Institute provided room for a museum to house the many items accumulated by that organization over the years. The general character of today's museum was set by the Halifax Mechanics Institute Museum. Of the many collections it held, by far the primary collection was the mineralogical material (Honeyman, 1874), to which the leading mineralogists of the time contributed. Individuals such as Messrs Alger and Jackson, Dr Abraham Gesner, and Mr Errol Boyd made frequent donations. The total number of minerals at that time was 990. Although not so numerous as the minerals, the paleontological and petrological collections were also important.

A proposal to establish a provincial museum was first made in 1862 by a committee made up of members of the Halifax Mechanics Institute Museum, the government, and the Exhibitions Commission. At the same time the provincial government approached the Reverend Dr David Honeyman, a well-known naturalist of the day, and asked him to assemble a collection of rocks, minerals, and fossils for the London International Exhibition. This was so successful that similar exhibits were prepared by Professor Henry How of Kings College, Windsor, Nova Scotia, for the Dublin and Paris exhibitions of 1865 and 1867 respectively. Dr Honeyman pointed out the value of the specimens gathered for the exhibitions and was quick to revive the proposal to establish a provincial museum for the preservation of these displays and to incorporate the material of the Halifax Mechanics Institute Museum. In 1868, by act of legislature, the Provincial Museum was established.

Even after Dr Honeyman's time, the museum continued to be a one-man institution with the appointment of Mr Harry Piers in 1899. Under the new curator the collections were catalogued and the holdings of the museum were organized and documented. The most accurate information on early collections has come from the Harry Piers catalogues. Also at that time the museum grew by one staff position: a cleaner.

Upon the death of Mr Piers in 1940, Mr Donald Crowdis was appointed as curator/director. Because of limited space for displays, all of the historical artifacts were placed in storage and the Museum Act was rewritten to establish the museum solely as a science institution. The name of the museum became The Nova Scotia Museum of Science. It grew rapidly under Mr Crowdis, and public awareness of the role of museums was greatly enhanced. In 1955 the History Branch of the museum was established at Citadel Hill, a famous fortress in Halifax, and a site frequented by tourists and residents alike. It was during this time that much of the geological material was packed and placed in storage.

From 1965 to 1983, Mr J. Lynton Martin was director and an ambitious program of museum development was carried out. For the first time in its history the museum acquired a building of its own and the History and Science Branches were combined under one roof and given the new name of Nova Scotia Museum (NSM). The new facility which opened in 1970 would now hold all the collections, with only the larger items placed in a storage centre at Mount Uniacke, approximately 30 km from the main institution.

State of the Geology Collections in 1974

When the author came on staff, some of the collections were in a state of disarray. Except for the Piers catalogues, no other collections information for the early specimens

Proceedings of the 1985 Workshop on Care and Maintenance of Natural History Collections. Edited by Janet Waddington and David M. Rudkin. Life Sciences Miscellaneous Publications. © Royal Ontario Museum, 1986.

existed. Only the mineralogical collections were well catalogued. The paleontology collection was for the most part accessioned but was not well identified, and the petrological collections were uncatalogued and distributed throughout many drawers.

A major program of collection documentation was undertaken beginning with the petrological material.

Geology Collections Documentation

In 1975 a visit was made to the National Inventory Program of the National Museum to discuss automation of geological collections. At that time, fields (a field being a unit of information) were set up for cataloguing, and a program was written so that geological records could be entered into the national system. Unfortunately the NSM had no staff to carry out the data entry. As a result, work proceeded instead on record preparation.

A new form was drawn up, containing all the fields used to record the details known about each specimen in the collection of rocks (the petrology collection). New catalogue cards and labels were prepared as well. This new form, called a Specimen Record Sheet, became the master accession and catalogue record (see Appendix). Combination of the two previous catalogue and accession forms saved duplication of effort.

The new system was then extended to the remaining geological collections. The mineral, gem, structural, economic, and fossil collections were all catalogued or recatalogued. Virtually all of the geological specimens were assessed and processed.

To prevent any confusion or loss of information, all manual catalogue card and specimen label systems were continued under the new cataloguing procedure.

Collections Systems Analysis

With the geological collections ready to be entered into an automated system, but no system yet available, attention was turned to the other natural history collections. The author and Mr Fred Scott, also of the Natural History Section, asked each curator or curatorial assistant to evaluate and describe the process of accessioning and cataloguing carried out by their unit of the Natural History Section. A detailed study was then made of the many varied procedures in use. Graphic illustrations of the procedures were compiled to make analyses easier, and to demonstrate to the non-curator the many repetitive tasks performed when cataloguing. One of these illustrations, a documentation critical path for the paleontology collection, is reproduced in Figure 1.

The study demonstrated the diversity of cataloguing systems in use within the section. Knowing the manual procedures in use, one could now estimate the time required to prepare records for automation and the time required for record input.

The significant recommendations of the report were: that the purchase of a system be made as soon as possible; that it be an in-house system; that it be able to communicate with the national data base; that the manual procedures already in use be continued; that backup copies of all the data disks be kept in another building; and that priorities be set for the entry of the backlog.

Automation a Reality

An opportunity presented itself in April 1983 to look seriously into automation and to implement the recommendations of the above-mentioned study. An investigation into available software which would carry out the desired tasks and procedures was then performed. All data base software programs that we could identify were investigated by reading trade magazines or by visits to computer supply houses. Before the visits to computer suppliers, we read extensively about each package to be demonstrated. It become obvious that most salespeople had no in-depth knowledge of the software packages they were selling.

The program known as DB Master seemed to be the best on the market at the time but it would only run on the Apple computer. We preferred the IBM personal computer for its capabilities and price. IBM offered a complete system with a 10-megabyte hard disc storage capacity for $12 000 whereas the Apple dealer offered a 5-megabyte hard disc system for the same price. To make the choice even more difficult IBM stated that DB Master would not be available for the IBM for three months—a risky wait as many promises of availability often do not come to fruition in the volatile computer industry. Unfortunately the software immediately available for data base work on the IBM did not have the capabilities that we were seeking. Because of circumstances beyond our control, the purchase had to be made within a few weeks. We therefore could not wait for a promised program and decided to investigate the Apple system in detail. Before the decision to purchase could be made, however, a test and evaluation process was performed.

While closely investigating the Apple System, we observed a demonstration of a software package produced by Apple, known as Quick File ///^{TM} (Quick File 3). It ran on Apple's new machine, the Apple /// (pronounced—Apple three). The Quick File program seemed to have everything we wanted—easy record input, standard entries, fast editing, fast and easy printouts of any information in any format, rapid sorts—and it was easy to learn. It would not accommodate all the necessary fields of information but it would act as a superb index. An upgrade of Quick File was promised which would use all of the

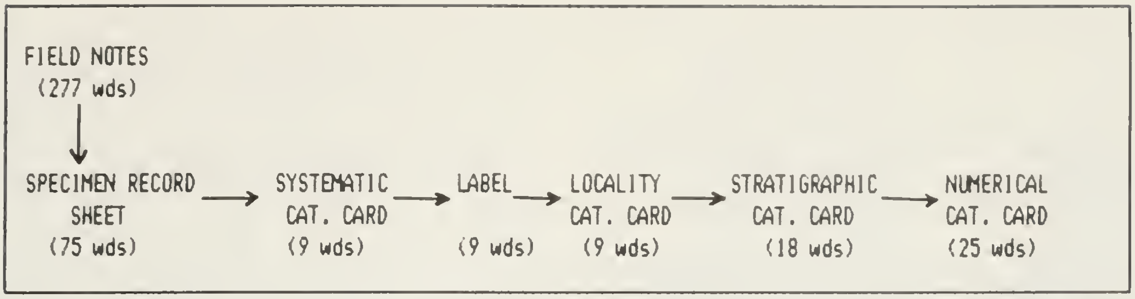


Fig. 1. For each fossil collected, the same information must be written by hand at least six times (wds=words, Cat=catalogue).

Apple ///'s 256K of RAM (random access memory) instead of only the 128K used by Quick File.

We decided to proceed with the purchase of the Apple system because it ran DB Master, and because Quick File /// had great possibilities.

DB Master turned out to be a disappointment as it would not address files on hard disc storage. Two other possibilities for data processing were then tried. The first program, called DataFax™, was designed for the processing of unstructured data. Natural history collections are highly structured and for this reason DataFax proved unsuitable. The second software package, known as Data Manager ///™, would accommodate all our fields of information and seemed to perform all the tasks required, but it was very tedious to set up and was also extremely slow on data searches.

Quick File, on the other hand, proved to be much more than expected. Although it would not hold the 50 or 60 fields of information required, it did have room for 15 fields with 80 characters of information in each. A list of vital fields was compiled. By grouping separate categories into one field, more categories than the limit of 15 could be used. For example, DATE and MANNER ACQUIRED were combined into one field called DT. & MAN. ACQ. A test run of 50 or 60 records was performed. Quick File proved to be the answer to all our geological data processing needs.

One staff position was acquired under a provincial winter and summer works program and input of the mineral collection was carried out. The 6108 records representing 12 000 specimens were all entered in nine months.

Approximately half-way through completion of the data entry, the upgrade of Quick File became available. It is produced not by Apple, but by Haba Systems Inc., and is called */// E-Z Pieces*™ (pronounced "three easy pieces" and abbreviated as 3EZP). This new package would read all the old files and made transfer of the information from them a very simple task. All files were converted in less than an hour.

At present the system is not used to communicate with PARIS (Pictorial Artifact Retrieval and Information System) of the National Museums Corporation. There is no impediment to this communication other than lack of funding to cover the purchase of the necessary hardware and software, and the establishment of an agreement with CHIN (Canadian Heritage Information Network).

Backlog priorities were not a problem as we entered the material on a first ready, first entered basis. This meant that the geological collections were done first as they were ready and required no preparation for conversion to an automated system. The mineral collection, being the largest, was entered first. The remaining natural history collections would be entered as soon as a data base for them had been set up and the appropriate entry fields had been selected.

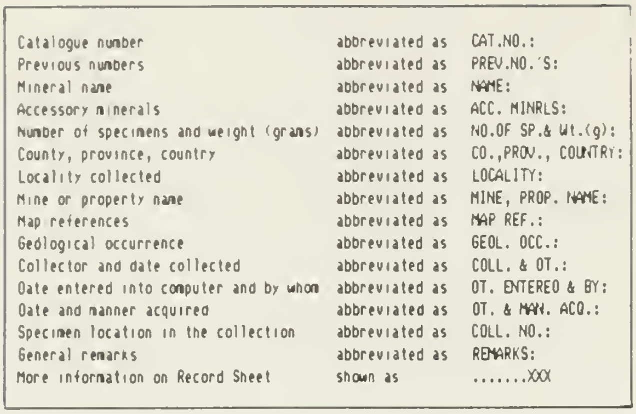
Collections Management Procedures in Use Today

The geological material is divided into eight collections. These include the mineral, petrological, vertebrate paleontology, invertebrate paleontology, paleobotanical, structural, economic minerals, and the gem collections. For purposes of brevity only the economic minerals collection will be discussed here, as the others are subject to similar procedures with only moderate variation.

As mentioned earlier for geology, the accessioning and cataloguing procedures have been combined into one operation. Moreover, at the NSM our accession number is part of the catalogue number. In this way only one record is created for the incoming specimen.

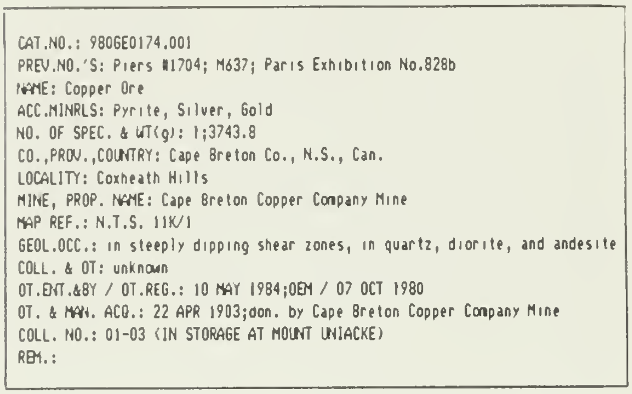
All the information about a particular specimen is recorded on a Specimen Record Sheet. The record sheet then becomes the new master information source for the specimen. For the economic minerals collection there are 62 fields of information. A field, as mentioned earlier, is a unit of information, such as the mineral's name, the locality from which it was collected, or the collector's name, etc.

The Appendix to this paper is a Specimen Record Sheet which contains the information about specimen number 980GE174.1. When completed, the sheet is given to the data entry operator who enters the information into the



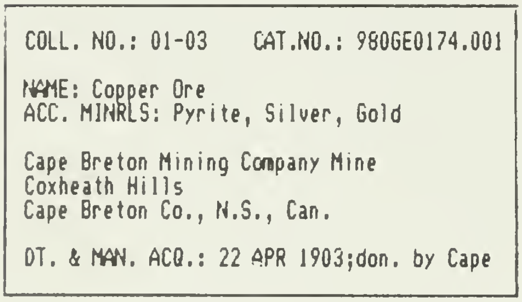
```
Catalogue number                          abbreviated as   CAT.NO.:
Previous numbers                          abbreviated as   PREV.NO.'S:
Mineral name                              abbreviated as   NAME:
Accessory minerals                        abbreviated as   ACC. MINRLS:
Number of specimens and weight (grams)    abbreviated as   NO.OF SP.& Wt.(g):
County, province, country                 abbreviated as   CO.,PROV., COUNTRY:
Locality collected                        abbreviated as   LOCALITY:
Mine or property name                     abbreviated as   MINE, PROP. NAME:
Map references                            abbreviated as   MAP REF.:
Geological occurrence                     abbreviated as   GEOL. OCC.:
Collector and date collected              abbreviated as   COLL. & DT.:
Date entered into computer and by whom    abbreviated as   DT. ENTERED & BY:
Date and manner acquired                  abbreviated as   DT. & MAN. ACQ.:
Specimen location in the collection       abbreviated as   COLL. NO.:
General remarks                           abbreviated as   REMARKS:
More information on Record Sheet          shown as         .......XXX
```

Fig. 2. The fields recorded in the computer.



```
CAT.NO.: 980GE0174.001
PREV.NO.'S: Piers #1704; M637; Paris Exhibition No.828b
NAME: Copper Ore
ACC.MINRLS: Pyrite, Silver, Gold
NO. OF SPEC. & WT(g): 1;3743.8
CO.,PROV.,COUNTRY: Cape Breton Co., N.S., Can.
LOCALITY: Coxheath Hills
MINE, PROP. NAME: Cape Breton Copper Company Mine
MAP REF.: N.T.S. 11K/1
GEOL.OCC.: in steeply dipping shear zones, in quartz, diorite, and andesite
COLL. & DT: unknown
DT.ENT.&BY / DT.REG.: 10 MAY 1984;DEM / 07 OCT 1980
DT. & MAN. ACQ.: 22 APR 1903;don. by Cape Breton Copper Company Mine
COLL. NO.: 01-03 (IN STORAGE AT MOUNT UNIACKE)
REM.:
```

Fig. 3. An example of a computer record (compare this to the full record as shown in the Appendix).



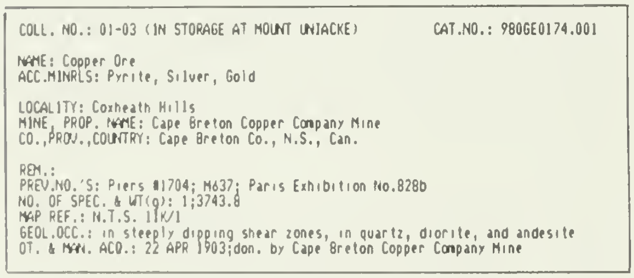
```
COLL. NO.: 01-03    CAT.NO.: 980GE0174.001

NAME: Copper Ore
ACC. MINRLS: Pyrite, Silver, Gold

Cape Breton Mining Company Mine
Coxheath Hills
Cape Breton Co., N.S., Can.

DT. & MAN. ACQ.: 22 APR 1903;don. by Cape
```

Fig. 4. Specimen label.



```
COLL. NO.: 01-03 (IN STORAGE AT MOUNT UNIACKE)          CAT.NO.: 980GE0174.001

NAME: Copper Ore
ACC.MINRLS: Pyrite, Silver, Gold

LOCALITY: Coxheath Hills
MINE, PROP. NAME: Cape Breton Copper Company Mine
CO.,PROV.,COUNTRY: Cape Breton Co., N.S., Can.

REM.:
PREV.NO.'S: Piers #1704; M637; Paris Exhibition No.828b
NO. OF SPEC. & WT(g): 1;3743.8
MAP REF.: N.T.S. 11K/1
GEOL.OCC.: in steeply dipping shear zones, in quartz, diorite, and andesite
DT. & MAN. ACQ.: 22 APR 1903;don. by Cape Breton Copper Company Mine
```

Fig. 5. Specimen catalogue card.

computer. Not all of the information can be entered (compare the Appendix with Fig. 2). As can be seen in the sample record from the computer printout (Fig. 3) only the key information has been entered for that specimen.

After entry of a number of specimen records, a printout of the data is obtained and the accuracy of the entered information is checked against the raw data on the specimen record sheet. When the information is all corrected, usually after three separate correcting cycles, the catalogue cards and specimen labels are then printed out. A specimen label and a catalogue card are shown in Figures 4 and 5.

Report Writing

Creation of reports in any format desired is no problem with this program. Searching and retrieval of the information is simple. 3EZP allows searches to be carried out on three criteria at one time. In the time we have been using it, there has been only one occasion where more than three criteria were required.

Once we have the appropriate collection in memory and the desired report format selected, the search involves entering the proper criteria and specifying their range and comparative information. The computer generates the list, which is then available to be sent to the screen, printer, or daisy-wheel printer. The list can also be reserved for a word processor file or it can be sent to a text file on disc. This provides a great range of possibilities for manoeuvring the data to any report or file desired.

Summary

The geological collections have played a key role in the development of the Nova Scotia Museum. Although suffering the many indignities of relocation and misuse, they have retained their intrinsic value for the researcher, the naturalist, and the general public. It is only now with the aid of rapid electronic data processing that the vast quantity of information contained in the collections can be made readily available for wide distribution.

This paper has provided a glimpse into some of the problems of, and most importantly, some of the solutions to the management of geological collections at the Nova Scotia Museum.

Addendum

It should be noted that the museum is about to undergo a systems analysis study to be carried out by the Department of Government Services. This will be done to determine the degree of automation required for all sections of the museum, and to determine the relationships among existing or required systems, either in-house, in-government, or external to both.

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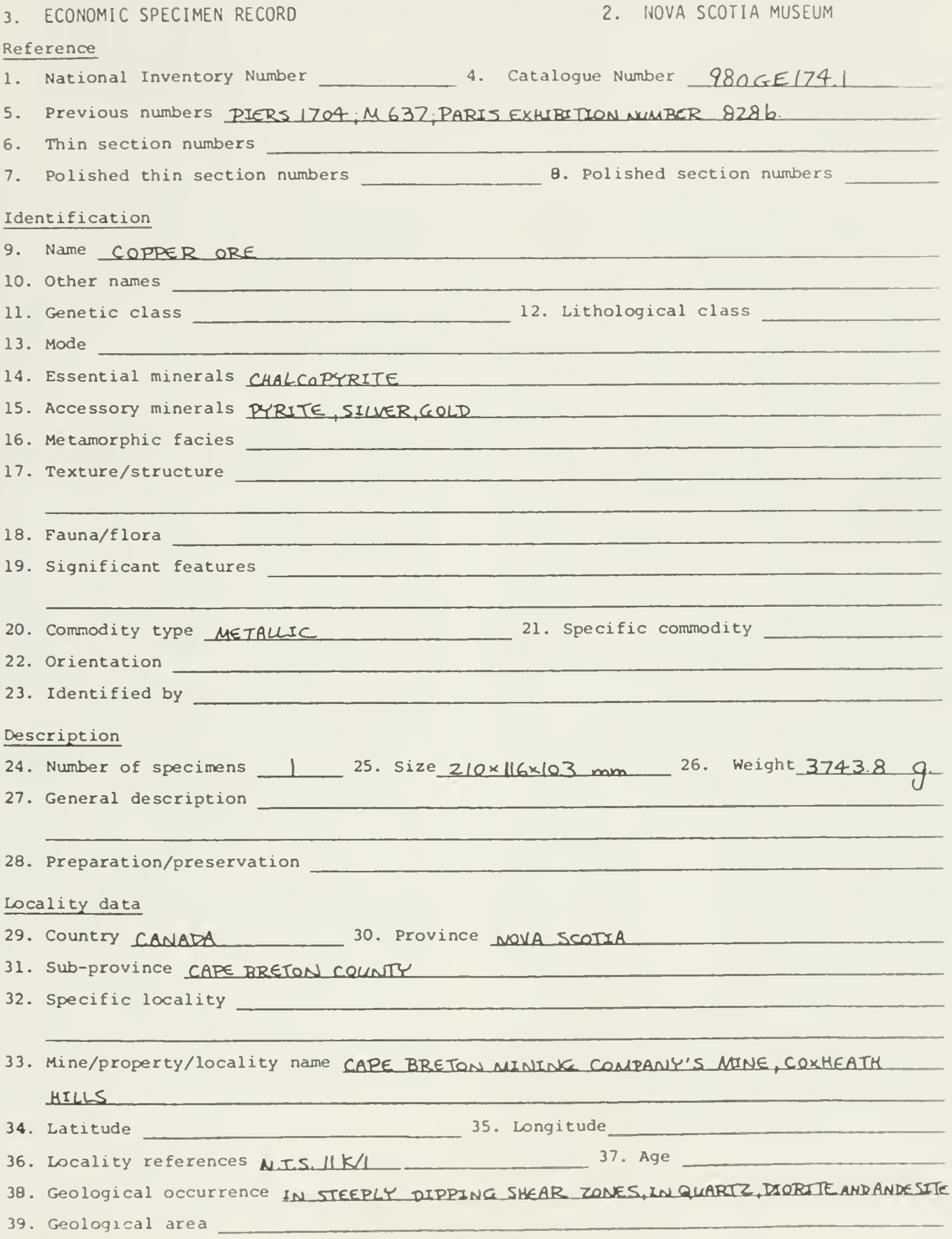
1982 An analysis of present information management systems in the Nova Scotia Museum Science Section, with recommendations. Unpublished report.

Appendix: Sample Specimen Record Sheet



3. ECONOMIC SPECIMEN RECORD
2. NOVA SCOTIA MUSEUM

Reference

1. National Inventory Number
4. Catalogue Number 980GE174.1
5. Previous numbers PIERS 1704; M 637; PARIS EXHIBITION NUMBER 828b.
6. Thin section numbers
7. Polished thin section numbers
8. Polished section numbers

Identification

9. Name COPPER ORE
10. Other names
11. Genetic class
12. Lithological class
13. Mode
14. Essential minerals CHALCOPYRITE
15. Accessory minerals PYRITE, SILVER, GOLD
16. Metamorphic facies
17. Texture/structure
18. Fauna/flora
19. Significant features
20. Commodity type METALLIC
21. Specific commodity
22. Orientation
23. Identified by

Description

24. Number of specimens 1
25. Size 210×116×103 mm
26. Weight 3743.8 g.
27. General description
28. Preparation/preservation

Locality data

29. Country CANADA
30. Province NOVA SCOTIA
31. Sub-province CAPE BRETON COUNTY
32. Specific locality
33. Mine/property/locality name CAPE BRETON MINING COMPANY'S MINE, COXHEATH HILLS
34. Latitude
35. Longitude
36. Locality references N.T.S. 11K/1
37. Age
38. Geological occurrence IN STEEPLY DIPPING SHEAR ZONES, IN QUARTZ, DIORITE AND ANDESITE
39. Geological area

Accession

40. Collector

41. Date collected

42. Date of registration OCT. 7, 1980

43. Date of acquisition APR. 22, 1903

44. Manner of acquisition DONATED

45. Purchase price

46. Source CAPE BRETON COPPER MINING COMPANY, COXHEATH, C.B.CO.

47. Owners and numbers

48. Location in collection 1-3

In storage at
Math. Annexe

49. Loaned to

50. Date loaned

51. History

Analytical/data reference

52. Physical properties determined

53. Optical properties

54. Crystallographic

55. X-ray data

56. Other data

57. Photographic record number

Other

58. References

59. Names of those entering data R.OGILVIE, R.GRANTHAM

60. Date data was entered

61. Remarks

62. Exchange

USES OF THE COMPUTER IN COLLECTION MANAGEMENT

SUZANNE B. McLAREN, HUGH H. GENOWAYS, and DUANE A. SCHLITTER
Section of Mammals, Carnegie Museum of Natural History, 4400 Forbes Avenue,
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ABSTRACT—In 1977, the Section of Mammals, Carnegie Museum of Natural History, began retroactive data capture of the research collection. Data were entered directly into the computer file from unedited handwritten catalogues. In 1979, curation of the entire collection began. The use of computer printouts has contributed substantially to the progress of the curatorial process. Conversely, curation has been of great assistance in upgrading data in the computer file.

Each specimen record, containing up to 43 separate data fields, can be viewed as a single unit on a video display terminal. Changes in the data may be submitted for an individual catalogue number or in batches of unlimited size. The greatest strength of the system is its ability to cross-reference any data field, both singly and in multiple combinations, for the production of a printed report. This capability is used frequently for answering inquiries, and is used almost daily for management and curation of the collection.

The computerization of the collection has made it possible to trace answers to a wide variety of questions that would otherwise have been prohibitive. This paper presents examples of methods used in locating lost and uncatalogued material, updating of taxonomic and geographic information, locating mismatched specimens, the generation of labels, and the production of cross-referencing files.

Introduction

The idea of computerizing museum collections first began to appear in the literature about 20 years ago. Technology and cost are beginning to make the undertaking of computerization projects feasible for most institutions. Although hundreds of collections among various disciplines had begun computerization by the late 1970s (Peebles and Galloway, 1982; Sarasan and Neuner, 1983), many projects failed because they were poorly conceived. Difficulties were compounded when crossing interdisciplinary lines within an institution. Considerable disagreement arose over how to treat scientific, historical, and art objects under the same system (Elisseff, 1970/1971). Yet evidence from a recent survey (McLaren, 1985) indicates that fewer than 30 of 360 mammal collections in North America had begun to be computerized by 1984.

The purpose of this paper is to present information that might be helpful to institutions that are now considering computerization. Within an interdisciplinary framework details of hardware, the types of computer users, and the specific uses made by the Section of Mammals will be described. Comments about the advantages and disadvantages of the system at the Carnegie Institute are presented not only as information but as encouragement for other computerized collections to follow suit.

Discussion

In 1976, the Carnegie Museum of Natural History undertook the task of computerizing collection data from several of its scientific sections. At that time, Dr John Sutton came to the Carnegie Museum of Natural History as programmer, and computer time was purchased through a service bureau. On-site hardware consisted of a keypunch machine. Data from the research collections of the sections of Mammals, Vertebrate Fossils, Reptiles and Amphibians, and Anthropology were placed on the computer file, as were twenty years of bird-banding data from the Section of Birds.

In 1979 a grant from the R. K. Mellon Foundation made it possible for the Carnegie Institute to purchase its own computer and supported on-going computer services to users throughout the Institute. The new system included a WANG VS 80 minicomputer with a WANG 2200 VS operating system, COBOL and BAL compilers, 512 KB Central Processing Unit with a 308 KB Diskette Drive, one 75 MB Disk Drive and two 288 MB Disk Drives. At that time, plans for computerization expanded to other sections of the Natural History Museum, several sections in the Museum of Art, and the Departments of Financial and General Services, Membership, and Development. Programming provided specific attention to the unique requirements of each section or department. While all participants shared the report writing program called "SADIE", other similarities were not forced onto the various sections and departments but incorporated when possible.

Programming for the new system was done commercially by Wang and APTECH, Inc., a Pittsburgh-based

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corporation. The programs are copyrighted by APTECH. Formats for data entry and loan programming had been established by John Sutton. When new programming began, the Section of Mammals submitted formats for label printing and masterlist reports, which were subsequently incorporated into the system.

Computerization of records from the research collection of the Section of Mammals began in 1977. During 1977 and 1978, prior to the installation of the Institute's minicomputer, data entry was performed by keypunch operators who rapidly entered collection data for 43 000 previously catalogued specimens. This phase is called retroactive data capture. Between 1978 and 1980, the data entry clerks continued to keep pace with cataloguing operations and entered data for approximately 22 000 additional specimens.

By 20 May 1980, the new hardware was in place and the first stages of programming adapted the 65 000 specimen mammal file to the new system. With funding from the National Science Foundation, the Section of Mammals purchased a Wang Serial Data Processing Workstation (CRT). Because the Section of Mammals is located in an annex building, two miles from the Carnegie Institute, it was necessary to provide a remote connection to the computer. This was accomplished with a 4800 Baud, closed line, full duplex Gandalf modem. However, this model has proven to be a poor choice, causing an eight-second delay in transmission to and from the computer.

Direct access to the computerized mammal files was possible by September 1980. Since then, data entry has been accomplished by personnel of the Section of Mammals. Software for writing reports, producing labels, and making file-wide changes had been completed and was accessible by January 1981. This proved to be not only convenient but increasingly essential as the process of curating the entire research collection progressed.

The data files were originally created by using the unedited, handwritten catalogues, dating back to 1896. This provided a convenient, if imperfect, set of records with which to work. Later, the necessary corrections could be made more rapidly using the computer.

At about the same time that computerization of the collection was begun, a project to curate the entire collection was undertaken. Curation has been supported by funding from the National Science Foundation, and would have been undertaken whether computerization had been involved or not; however, curation and updating of data files complement each other well. Curation of the collection included comparisons between computer printouts and skin tags for each specimen in the collection. As this massive project progresses, missing specimens and specimens with questionable records are found, the need for sweeping taxonomic and geographic changes is discovered, and outside inquiries about collection holdings continue to be received. The computer has provided a means for handling many tasks that previously required much more time and sometimes tedious effort. The following examples outline the basic daily uses of our computerized collection records.

DATA ENTRY AND MAINTENANCE

Specimens are initially catalogued in handwritten ledgers according to established data standards for mammal collections (Williams, Smolen, and Brigida, 1979). Data are then entered into the computer files using a video display terminal. The record entry screen (Fig. 1) has been formatted in the same order as the handwritten catalogue is read from left to right. It is not necessary for the user to be prompted because all categories of specimen data appear on the screen at the same time.

After a new record is entered, the catalogue number automatically advances by one digit while all other data remain the same until modified or deleted. Previously entered records can be recalled for examination or modification using the same screen.

Amendments to records located throughout the file are accomplished using a "Global Change" (Fig. 2) program which employs the use of simple conditional statements for locating the information to be modified. This feature not only saves time when entering repetitious data but also enhances the accuracy of all records. It finds all instances of the error being sought and makes certain that changes are consistently correct as re-entered.

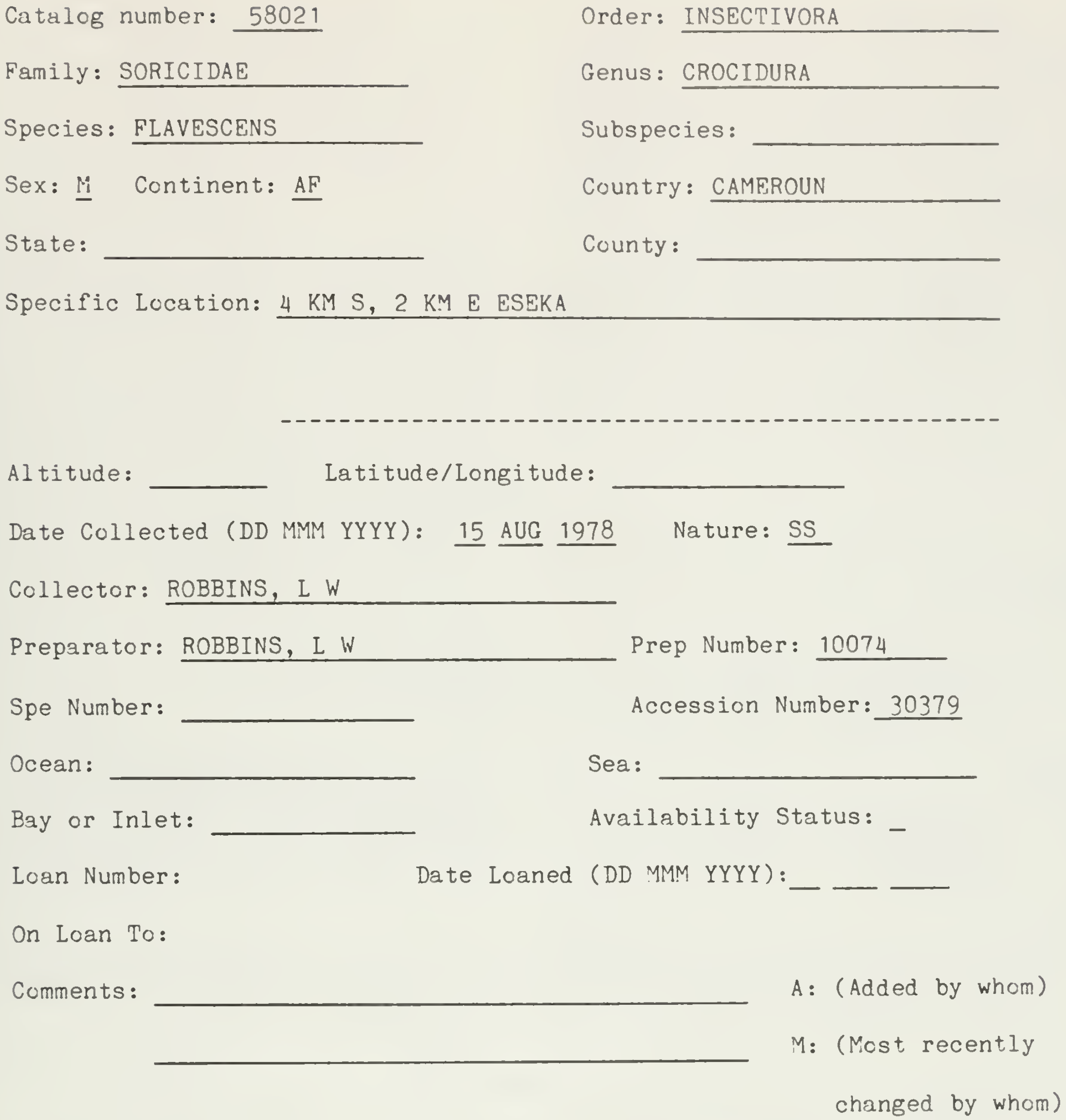
STANDARD FORMATS

The Master List format (Fig. 3) facilitates the presentation of data without the need for lengthy explanation to a person unfamiliar with the collection. For that reason, this is the format most often used when providing responses to outside inquiries. This format may be modified, if desired, and categories may be suppressed. The Master List is also used extensively in the curation process in order to cross-check all available data on skin tags, skull tags, and unedited catalogues.

New skeletal labels are being computer-generated for all specimens in the collection as curation proceeds and the data file is upgraded. Labels are initially produced as shown in Figure 4 and later photoreduced to a size that is suitable for insertion in a 4 dram vial.

PROBLEM SOLVING

By undertaking retroactive data capture directly from unedited catalogues, the computer file was quickly built up. However, nearly 43 000 specimens had been catalogued before data standards became a consideration. Between 1896 and 1977, many taxonomic and geographic name changes had also taken place.



Catalog number: 58021 Order: INSECTIVORA

Family: SORICIDAE Genus: CROCIDURA

Species: FLAVESCENS Subspecies: ______

Sex: M Continent: AF Country: CAMEROUN

State: ______ County: ______

Specific Location: 4 KM S, 2 KM E ESEKA

Altitude: ______ Latitude/Longitude: ______

Date Collected (DD MMM YYYY): 15 AUG 1978 Nature: SS

Collector: ROBBINS, L W

Preparator: ROBBINS, L W Prep Number: 10074

Spe Number: ______ Accession Number: 30379

Ocean: ______ Sea: ______

Bay or Inlet: ______ Availability Status: _

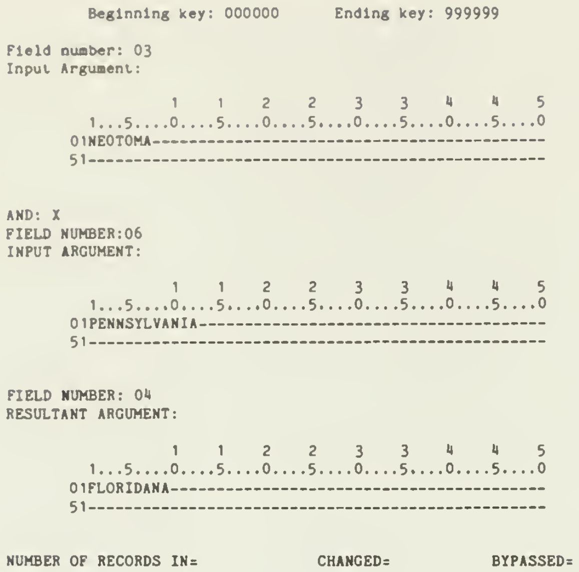
Loan Number: Date Loaned (DD MMM YYYY): __ ___ ____

On Loan To:

Comments: ______ A: (Added by whom)

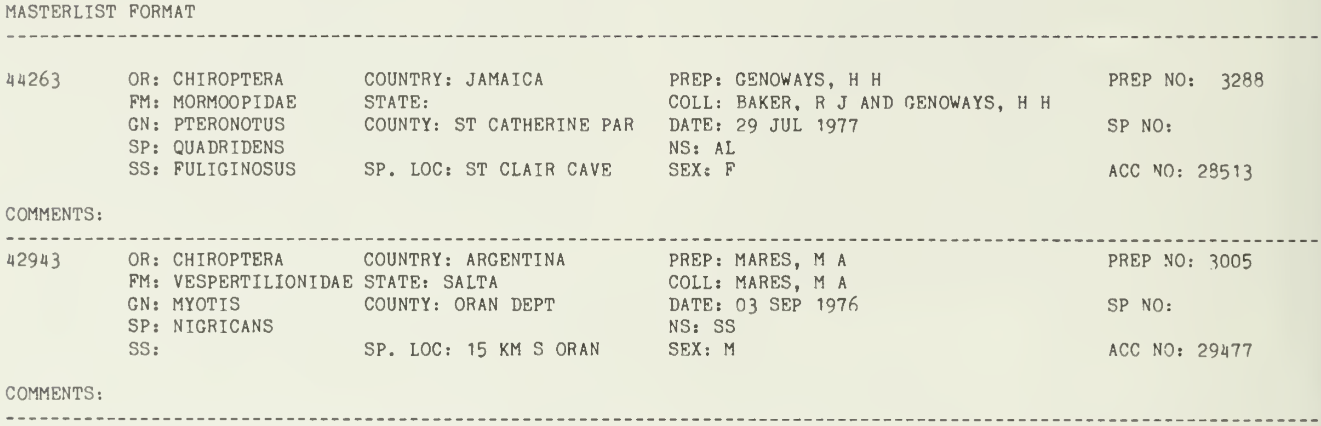
______ M: (Most recently changed by whom)

Fig. 1. Specimen Record Entry Screen in use by the Section of Mammals, Carnegie Museum of Natural History.



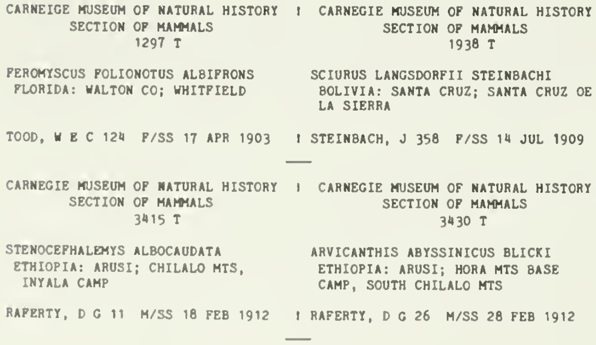
```
         Beginning key: 000000      Ending key: 999999

Field number: 03
Input Argument:

                   1    1    2    2    3    3    4    4    5
         1...5....0....5....0....5....0....5....0....5....0
       01NEOTOMA-----------------------------------------------
       51------------------------------------------------------


AND: X
FIELD NUMBER:06
INPUT ARGUMENT:

                   1    1    2    2    3    3    4    4    5
         1...5....0....5....0....5....0....5....0....5....0
       01PENNSYLVANIA------------------------------------------
       51------------------------------------------------------


FIELD NUMBER: 04
RESULTANT ARGUMENT:

                   1    1    2    2    3    3    4    4    5
         1...5....0....5....0....5....0....5....0....5....0
       01FLORIDANA---------------------------------------------
       51------------------------------------------------------


NUMBER OF RECORDS IN=            CHANGED=           BYPASSED=
```

Fig. 2. Global Change Screen which is used for batch processing of corrections.



```
MASTERLIST FORMAT
------------------------------------------------------------------------------------------------

44263      OR: CHIROPTERA       COUNTRY: JAMAICA           PREP: GENOWAYS, H H                  PREP NO:  3288
           FM: MORMOOPIDAE      STATE:                     COLL: BAKER, R J AND GENOWAYS, H H
           GN: PTERONOTUS       COUNTY: ST CATHERINE PAR   DATE: 29 JUL 1977                    SP NO:
           SP: QUADRIDENS                                  NS: AL
           SS: FULIGINOSUS      SP. LOC: ST CLAIR CAVE     SEX: F                               ACC NO: 28513

COMMENTS:
------------------------------------------------------------------------------------------------
42943      OR: CHIROPTERA       COUNTRY: ARGENTINA         PREP: MARES, M A                     PREP NO: 3005
           FM: VESPERTILIONIDAE STATE: SALTA               COLL: MARES, M A
           GN: MYOTIS           COUNTY: ORAN DEPT          DATE: 03 SEP 1976                    SP NO:
           SP: NIGRICANS                                   NS: SS
           SS:                  SP. LOC: 15 KM S ORAN      SEX: M                               ACC NO: 29477

COMMENTS:
------------------------------------------------------------------------------------------------
```

Fig. 3. Examples of the Masterlist format used for collection management and for answering outside inquiries regarding specimens in the Section of Mammals, Carnegie Museum of Natural History.



```
CARNEIGE MUSEUM OF NATURAL HISTORY  !  CARNEGIE MUSEUM OF NATURAL HISTORY
        SECTION OF MAMMALS                      SECTION OF MAMMALS
              1297 T                                 1938 T

PEROMYSCUS POLIONOTUS ALBIFRONS        SCIURUS LANGSDORFII STEINBACHI
 FLORIDA: WALTON CO; WHITFIELD          BOLIVIA: SANTA CRUZ; SANTA CRUZ OE
                                        LA SIERRA

TOOD, W E C 124  F/SS 17 APR 1903   ! STEINBACH, J 358  F/SS 14 JUL 1909
                                   ___

CARNEGIE MUSEUM OF NATURAL HISTORY  !  CARNEGIE MUSEUM OF NATURAL HISTORY
        SECTION OF MAMMALS                      SECTION OF MAMMALS
              3415 T                                3430 T

STENOCEPHALEMYS ALBOCAUDATA            ARVICANTHIS ABYSSINICUS BLICKI
 ETHIOPIA: ARUSI; CHILALO MTS,          ETHIOPIA: ARUSI; HORA MTS BASE
  INYALA CAMP                           CAMP, SOUTH CHILALO MTS

RAFERTY, D G 11  M/SS 18 FEB 1912   ! RAFERTY, D G 26  M/SS 28 FEB 1912
                                   ___
```

Fig. 4. Examples of the format for skeletal labels used by the Section of Mammals, Carnegie Museum of Natural History. These labels will be reduced in size for inclusion inside skull vials.

The report writing program allows cross-referencing of any data field and formatting of output is very flexible. The generation of "vocabulary lists" helps to pinpoint words that may be ignored by the computer when a specific search is made. For example, vocabulary lists can find misspellings or different ways in which the same locality has been entered (Fig. 5).

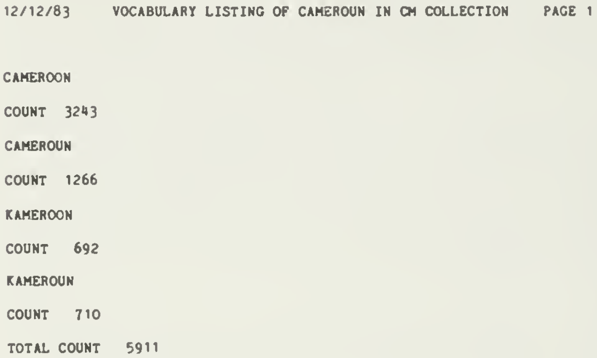
When a specimen is found without a catalogue number, but a field number is visible, a program requesting a listing of all specimens bearing the desired preparator's number can be extremely helpful (Fig. 6). Furthermore, this type of listing is useful in determining whether a specimen has, in fact, been catalogued. Listings of specimens prepared by a single individual are helpful in locating mismatched and uncatalogued specimens as well (Fig. 7).

Upgrading taxonomic and geographic records can be done in a variety of ways depending on the problem encountered. A system that allows a great deal of flexibility provides the programmer with the opportunity to use logic statements to manipulate the results as needed. For example, it was discovered that numerous specimens of *Napaeozapus* from Pennsylvania had been given the wrong subspecies name. However, the name was good for other specimens in the collection. By looking for records of *Napaeozapus* from Pennsylvania and replacing only the subspecies names for these particular *Napaeozapus*, the job can be completed with one electronic sweep through the file in five minutes.

Every printout produced in the Section of Mammals is used as a means of detecting hidden data entry errors. Subsequently, unrelated programs are developed to find any repetitions of the targeted error. In Figure 8, a listing of specimens from Bolivia shows a number of misspellings as well as the need for some taxonomic name changes.

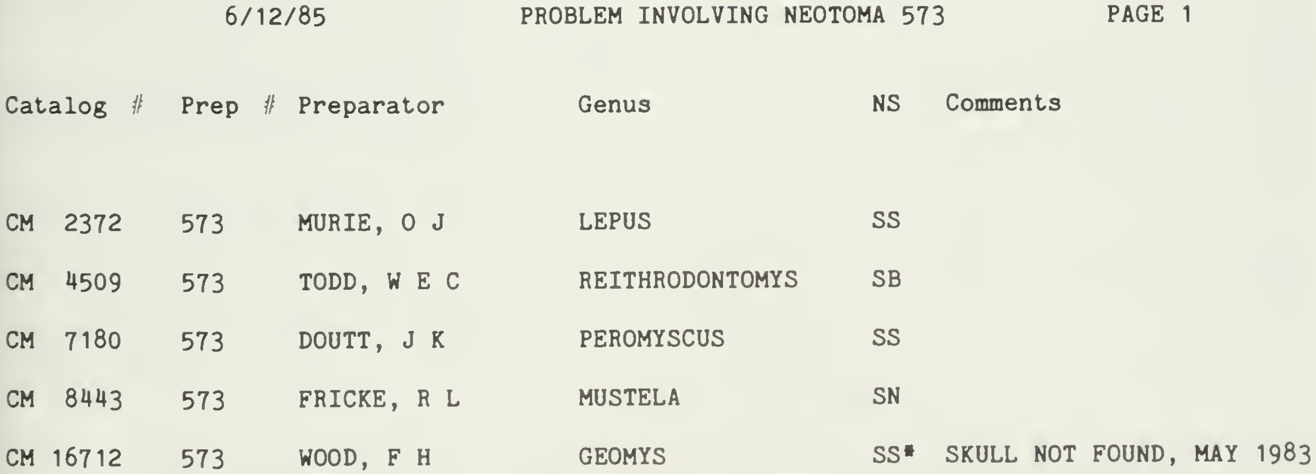
Conclusions

After four and one-half years of experience with the system in place at the Carnegie Museum of Natural



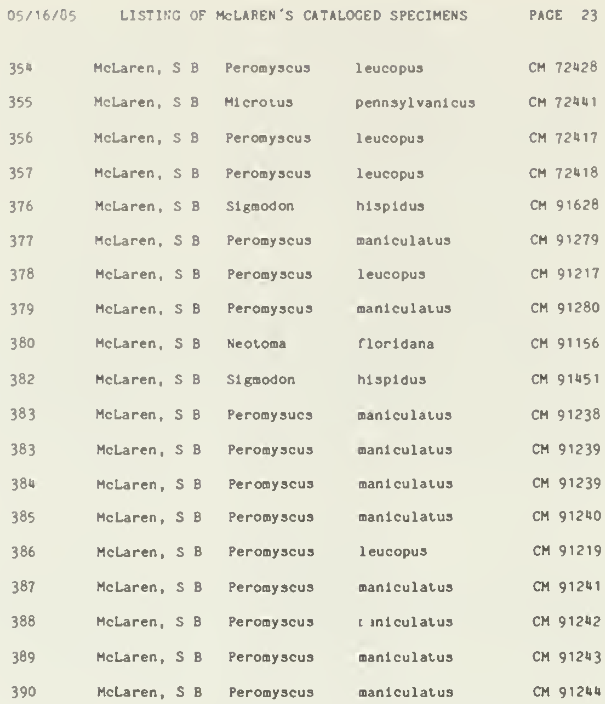
```
12/12/83     VOCABULARY LISTING OF CAMEROUN IN CM COLLECTION     PAGE 1

CAMEROON

COUNT  3243

CAMEROUN

COUNT  1266

KAMEROON

COUNT   692

KAMEROUN

COUNT   710

TOTAL COUNT   5911
```

Fig. 5. Reproduction of a single page print-out of a "vocabulary list". The various spellings of the word "Cameroun" in the mammal computer file at the Carnegie Museum of Natural History are used in this example. This information search is used when the need for corrections is suspected so that the size of the problem can be ascertained.



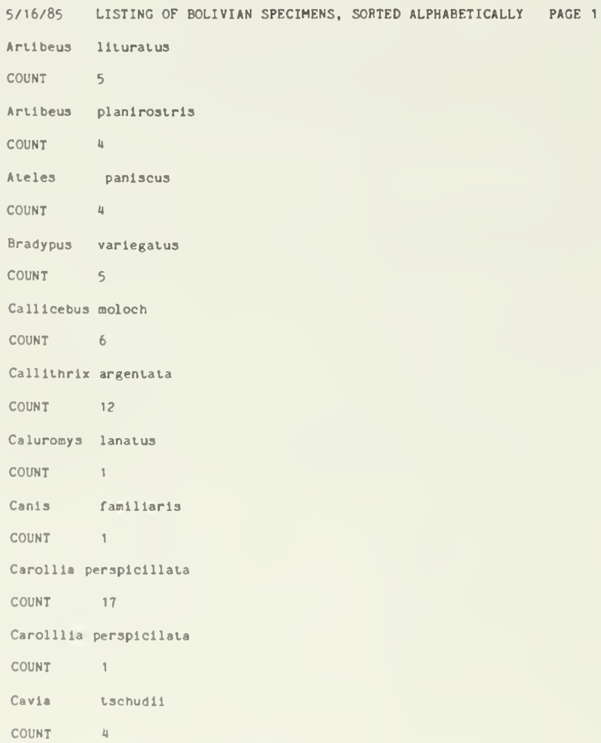
```
        6/12/85             PROBLEM INVOLVING NEOTOMA 573           PAGE 1

Catalog #   Prep #  Preparator          Genus            NS   Comments



CM  2372    573     MURIE, O J          LEPUS            SS

CM  4509    573     TODD, W E C         REITHRODONTOMYS  SB

CM  7180    573     DOUTT, J K          PEROMYSCUS       SS

CM  8443    573     FRICKE, R L         MUSTELA          SN

CM 16712    573     WOOD, F H           GEOMYS           SS*  SKULL NOT FOUND, MAY 1983
```

Fig. 6. Listing of all field numbers 573, in search of a matching specimen. A *Neotoma* skull with a label bearing the number 573 did not prove to be an accurate match. This listing led to the discovery of a previously mismatched *Geomys* with which the *Neotoma* tag had been switched.



```
05/16/85      LISTING OF McLAREN'S CATALOGED SPECIMENS        PAGE  23

354        McLaren, S B   Peromyscus     leucopus           CM 72428
355        McLaren, S B   Microtus       pennsylvanicus     CM 72441
356        McLaren, S B   Peromyscus     leucopus           CM 72417
357        McLaren, S B   Peromyscus     leucopus           CM 72418
376        McLaren, S B   Sigmodon       hispidus           CM 91628
377        McLaren, S B   Peromyscus     maniculatus        CM 91279
378        McLaren, S B   Peromyscus     leucopus           CM 91217
379        McLaren, S B   Peromyscus     maniculatus        CM 91280
380        McLaren, S B   Neotoma        floridana          CM 91156
382        McLaren, S B   Sigmodon       hispidus           CM 91451
383        McLaren, S B   Peromysucs     maniculatus        CM 91238
383        McLaren, S B   Peromyscus     maniculatus        CM 91239
384        McLaren, S B   Peromyscus     maniculatus        CM 91239
385        McLaren, S B   Peromyscus     maniculatus        CM 91240
386        McLaren, S B   Peromyscus     leucopus           CM 91219
387        McLaren, S B   Peromyscus     maniculatus        CM 91241
388        McLaren, S B   Peromyscus     maniculatus        CM 91242
389        McLaren, S B   Peromyscus     maniculatus        CM 91243
390        McLaren, S B   Peromyscus     maniculatus        CM 91244
```

Fig. 7. Listings of specimens prepared by a single collector can be helpful in tracking down missing specimens and in determining whether specimens have been catalogued.



```
5/16/85    LISTING OF BOLIVIAN SPECIMENS, SORTED ALPHABETICALLY   PAGE 1
Artibeus   lituratus
COUNT      5
Artibeus   planirostris
COUNT      4
Ateles      paniscus
COUNT      4
Bradypus   variegatus
COUNT      5
Callicebus moloch
COUNT      6
Callithrix argentata
COUNT      12
Caluromys  lanatus
COUNT      1
Canis      familiaris
COUNT      1
Carollia perspicillata
COUNT      17
Carolllia perspicilata
COUNT      1
Cavia      tschudii
COUNT      4
```

Fig. 8. Indirect queries for information often net errors that would not have been found by asking for the proper information directly. For example, in this listing of specimens from Bolivia there are misspellings for *Carollia* that would not have been reported in a program that had asked specifically for *Carollia*.

History/Carnegie Institute, several observations can be made for the benefit of those who are about to undertake the computerization process.

1) A good systems analysis is essential before computerization is begun (Sarasan and Neuner, 1983).

2) It is very helpful to investigate and compare the ways other collections have approached the process before you set up your own system.

3) Flexibility in formatting and report writing is our greatest asset. Lack of computer disk space is quickly becoming our greatest liability.

4) There is little "down time" due to system failure but we are rapidly running out of available disk space and have been studying the best means of up-grading our system. This bears out John Sutton's (in press) contention that computer system turn-over time is about four to five years.

5) The computer has been immeasurably helpful in daily collection management procedures as well as the strenuous task of collection-wide curation. The flexibility of our software has made it possible to adapt to new situations and work around system limitations, although we have had virtually no new programming since 1981. However, there is no substitute for being able to reprogram existing software. No matter how good the original programming is, the human mind will eventually want to ask new and different questions.

6) Ownership of the source program should be non-negotiable.

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THE CARD-VIAL SYSTEM FOR THE STORAGE OF SMALL VERTEBRATE FOSSILS

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ABSTRACT—Fossil collections include many small specimens which appear lost in specimen boxes. They can be held by two wads of padding in a glass shell vial which is attached to a cardboard specimen label. This system will afford protection, provide easy visual access to data, allow the visual inspection of fossils without opening the containers, and maximize the number of fossils which can be kept in a drawer.

Introduction

When choosing containers and methods for the storage of fossils a number of criteria must be considered. The most significant criteria are:

1) The fossil must be supported and protected.
2) The fossil should not be tangled in any supporting or padding material.
3) The container should not roll or be prone to tipping.
4) The materials used should not contain contaminants which could cause specimen deterioration.
5) Catalogue numbers and card data should be clearly visible.
6) The fossil should be easily inspected, preferably without removing it from its container.
7) Access to the specimen should be easy.
8) The size of the labels and containers should be comfortable to handle.
9) Space should be conserved in storage cabinets.
10) The method should be inexpensive and efficient.
11) Adhesive should not be used to fasten the specimen to a support.

For small specimens such as individual skeletal elements of rodents, birds, and fish, etc., a number of techniques are in common usage. They include pill boxes, open trays or plastic boxes padded with absorbent cotton, teeth glued to card mounts or pins inside vials, and custom mounts. Unfortunately these techniques fail to meet one or more of the selection criteria. At the Paleobiology Division of the National Museum of Natural Sciences the card-vial system has been used effectively for about 10 years for storing several thousand small vertebrate fossil remains.

Materials and Methods

The card-vial system (Fig. 1) is a very simple technique employing glass shell vials ranging in size from 12 mm in diameter × 35 mm long to 15 mm in diameter × 45 mm long, standard Paleobiology Division specimen card labels, absorbent cotton, and five-minute epoxy resin adhesive. Details of the method, briefly noted by Harington (1977) and Fitzgerald (1982), are as follows:

1) A patch of white automotive enamel is painted on the vial.
2) Specimen data are recorded with India ink on the card and the catalogue number is also put on the white enamel patch in case the card and vial become separated.
3) The catalogue number on the vial is protected with a thin coating of Vinac B-15™ dissolved in 85% ethanol/15% methanol (Vinac B-15 is a polyvinyl acetate manufactured by Air Products and Chemicals, Incorporated).
4) The specimen is supported in the vial between two wads of absorbent cotton or other padding material similar to a technique used by Kaplan (1979) to ship archaeological specimens.
5) The vial is cleaned with acetone to ensure good adhesion and is attached to the back of the card using five-minute epoxy resin adhesive. It is positioned horizontally in the middle of the card with its mouth flush with the edge of the card (first attempts using cellulose acetate base household cement failed after about five years causing the card to separate from the vial).
6) In the cabinet drawers, card-vials are organized one behind the other in rows. Even when tightly packed, catalogue numbers and identifications can be read without moving the vials (Fig. 2).
7) Cardboard trays are used to subdivide specimens into taxonomic groups within drawers.

To facilitate writing on the specimen cards, it is an advantage to use an inverted cardboard tray with a slot the size of a vial cut in it.

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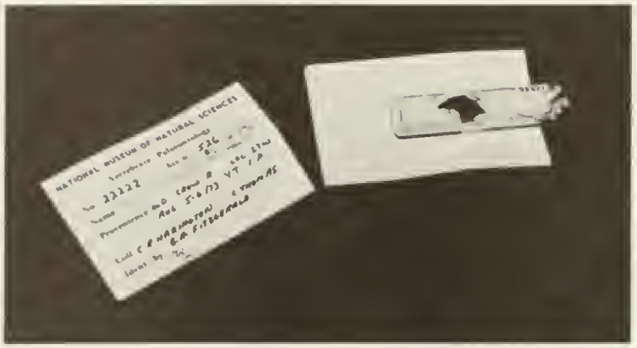

Fig. 1. Front and back views of a card-vial. In this case a rodent jaw is supported by two wads of acid-free tissue.

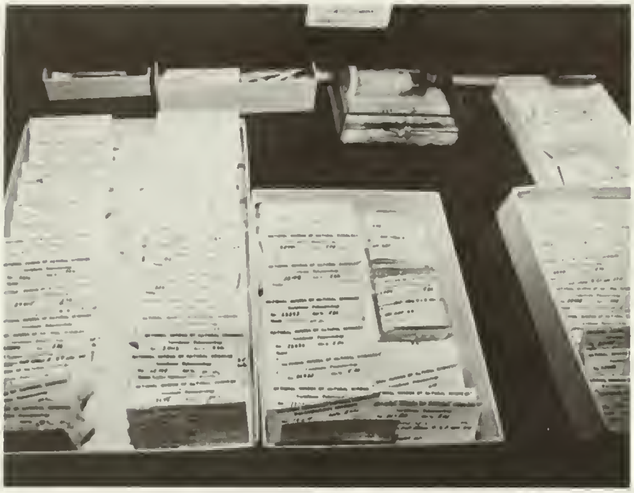

Fig. 2. Card-vials in a storage cabinet at the Paleobiology Division, National Museums of Canada. The high storage density is evident, while specimen data are clearly visible on the cards. The use of trays for taxonomic groupings within drawers is also illustrated.

Discussion

With the card-vial system the criteria for an adequate storage system are met. Each fossil is supported by two wads of padding and is protected within a vial. Further protection is provided by the card which is attached to the vial and helps prevent it from rolling. Absorbent cotton has been used as padding but for some specimens it has not been entirely satisfactory. The problem is that for some fossils with rough surfaces such as broken ends, exposed cancellous bone, or cracks, small fibres which are difficult to remove can cling to the fossils. Sometimes fossils even become entangled to the extent that fragile pieces are pulled from them. For such specimens, neutral acid free tissue or cotton fabric will most probably correct the problem and presently investigations are being carried out on their suitability as alternate padding materials. The use of absorbent cotton, however, will not be completely discontinued as it is a superior padding material and poses no problems for many fossils.

Some materials contain contaminants which in time could damage fossils. Acids from labels or padding materials could react with carbonates in fossils and conversely alkalies from buffered materials could break down the collagen in partially mineralized bone. It is therefore necessary to use unbuffered materials with a pH in the range of 6 to 7. Unbuffered acid-free tissue and some types of natural-fibre absorbent cotton or cotton fabric which contain no additives (e.g., sizes or optical brighteners) fall into this pH range. High quality cotton fabrics of this type are available from: Testfabrics Inc., P.O. Drawer O, 200 Blackford Ave., Middlesex, N.J., 08846, U.S.A.

Epoxy resins are excellent adhesives for glass and their tendency to yellow (Downs, 1984) is not significant in this application. It should be noted that the rapid curing formulations of epoxy resin are much more convenient to use than the slower curing types.

When the card-vials are placed in drawers, specimen data are readily visible without handling the vial. Specimens can quickly be inspected through the vials without actually touching or removing them, and only those required for study need to be handled. Access to the fossil is quickly achieved by removal of a single wad of padding. This reduction in handling lowers the risk of damage. In contrast, when boxes are used the labels are usually tucked beside or below the padding resulting in extra handling of specimens.

Although when considering the size of the specimen containers a compromise is usually involved, some general statements can be made. They should be comfortable to handle. Very small containers save space but increase the risk of misplacing or damaging specimens. They also require the use of slow micro-labelling techniques. If larger labels are used with very small containers, they are usually left loose in the drawers and can become separated from the specimens. In either case, problems can arise in locating individual specimens. Large containers provide adequate labelling areas but take up excess storage space. There is also the risk that small fossils can become ''lost'' within the padding. The card-vial system appears to be a reasonable compromise.

It should be noted that with the card-vial system, adhesive is not used to support the fossil. Even if water-soluble adhesives are used, as suggested by Rixon (1976:266), the fossil can still be damaged. Some fossils react adversely to water. Others have invisible cracks which are held together by the irregularities in the surfaces and a small amount of water can lubricate the joints causing them to fail.

The card-vial system is simple and fast, so that large numbers of fossils can be processed easily, and all the materials are inexpensive. Space is conserved in cabinets as the card-vials fit neatly and compactly into drawers.

There are obvious size limitations to the system and there comes a point where it is more reasonable to use specimen boxes rather than larger vials. For very small specimens, like individual rodent teeth, it is better to use micro-paleontological depression slides with removable coverslips. Such small specimens cannot be supported properly within a card-vial. The technique requires that the specimen be reasonably solid as support is not complete; therefore, for very fragile specimens better support is required. A very few specimens are of such unique value that individually designed storage containers and supports may be considered. An example of a custom mount is Rixon's (1976) mount for the storage of small jaws, but many other designs are possible.

Conclusions

The card-vial system has proved to be an adequate storage method for many small vertebrate fossils provided that they are solid enough to be supported by two wads of padding. The method has removed many potential sources of damage inherent in other storage techniques and present investigations should remove the problem of padding fibres sticking to some fossils. The use of card-vials has resulted in an observed reduction in the amount of damage sustained by fossils, while maintaining a high storage density.

Acknowledgements

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CURATING AND DISPLAYING COLLECTIONS OF MICROFUNGI

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ABSTRACT—The University of Alberta Microfungus Collection and Herbarium (UAMH) preserves dried colonies of fungal genotypes on cellophane. When mounted on cardboard frames, these specimens make attractive presentations and provide a durable record of the colonial and microscopic morphology. UAMH also maintains photomicrographs and *camera lucida* drawings of the majority of strains in the collection. These materials are filed vertically in folders in conveniently accessible file drawers, rather than on traditional, large herbarium sheets. The dried colonies, photomicrographs, and drawings provide both the scientist and the layman with a multidimensional characterization of each strain. Information on nearly all of the 5000 accessions in UAMH can be accessed by an on-line data base mediated through the Stanford Public Information Retrieval System (SPIRES) program.

Introduction

Established in 1960, The University of Alberta Microfungus Collection and Herbarium (UAMH) contains more than 5000 different, living genotypes of filamentous fungi and is an internationally and nationally recognized reference and research facility. Among collections of filamentous fungi, the UAMH ranks eighth largest in the world and second largest in Canada. Using techniques which ensure genetic stability, the UAMH preserves a unique collection of fungal strains important to medicine, agriculture, forestry, and industry. In spite of their intricate beauty, and great biological and economic importance, microfungi are rarely displayed to the public in scientific exhibits. This is due, at least in part, to the difficulty of preserving and curating meaningful herbarium material in such a way that it has significance to both the professional mycologist and the public.

Curatorial procedures which include techniques of preserving microfungi, in such a manner that they can be both used by the scientific community and appreciated by casual visitors and members of the public, have been developed at UAMH.

UAMH Curatorial Procedures

Curatorial procedures at UAMH (Fig. 1) are designed to meet seven interrelated objectives.

1) Facilitate access to living strains and specimens by maintaining an on-line data base which can generate a catalogue of strains.

2) Facilitate retrieval of biochemical and other data for multi- and inter-disciplinary uses.

3) Maintain all accessions in an accurate and durable form. This facilitates reference and identification procedures since the morphological characters of preserved strains are permanently displayed.

4) Provide an identification service for microfungi.

5) Preserve living strains in a manner that ensures their genetic stability.

6) Distribute cultures to scientists in many different disciplines.

7) Encourage and conduct in-house and collaborative taxonomic research.

On arriving at UAMH, fungi are cultured on various types of media and under different growing conditions. The fungus is then identified by comparison with similar accessions and with data in the literature. When a name is found, the sender is notified and the curator then decides if UAMH requires the strain as part of the permanent collection. If the species is well represented in the collection and the new strain is not unique in any way, it is discarded. Unique variants and taxa not already in the collection are accessioned into UAMH as follows:

1) Each strain is assigned a UAMH accession number.

2) Numbered strains are grown on cellophane on a variety of media, for preparation of dried colonies.

3) Permanent microscopic slides, drawings, and photographs are prepared.

4) Strain accession data are entered into the Stanford Public Information Retrieval System (SPIRES) data base and labels are generated for herbarium folders.

5) Strains are preserved by freezing at −20°C and/or by lyophilization.

Herbarium Specimens

Herbarium specimens of fungi have traditionally been treated in much the same manner as green plants, that is,

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UAMH ACCESSION PROCEDURES

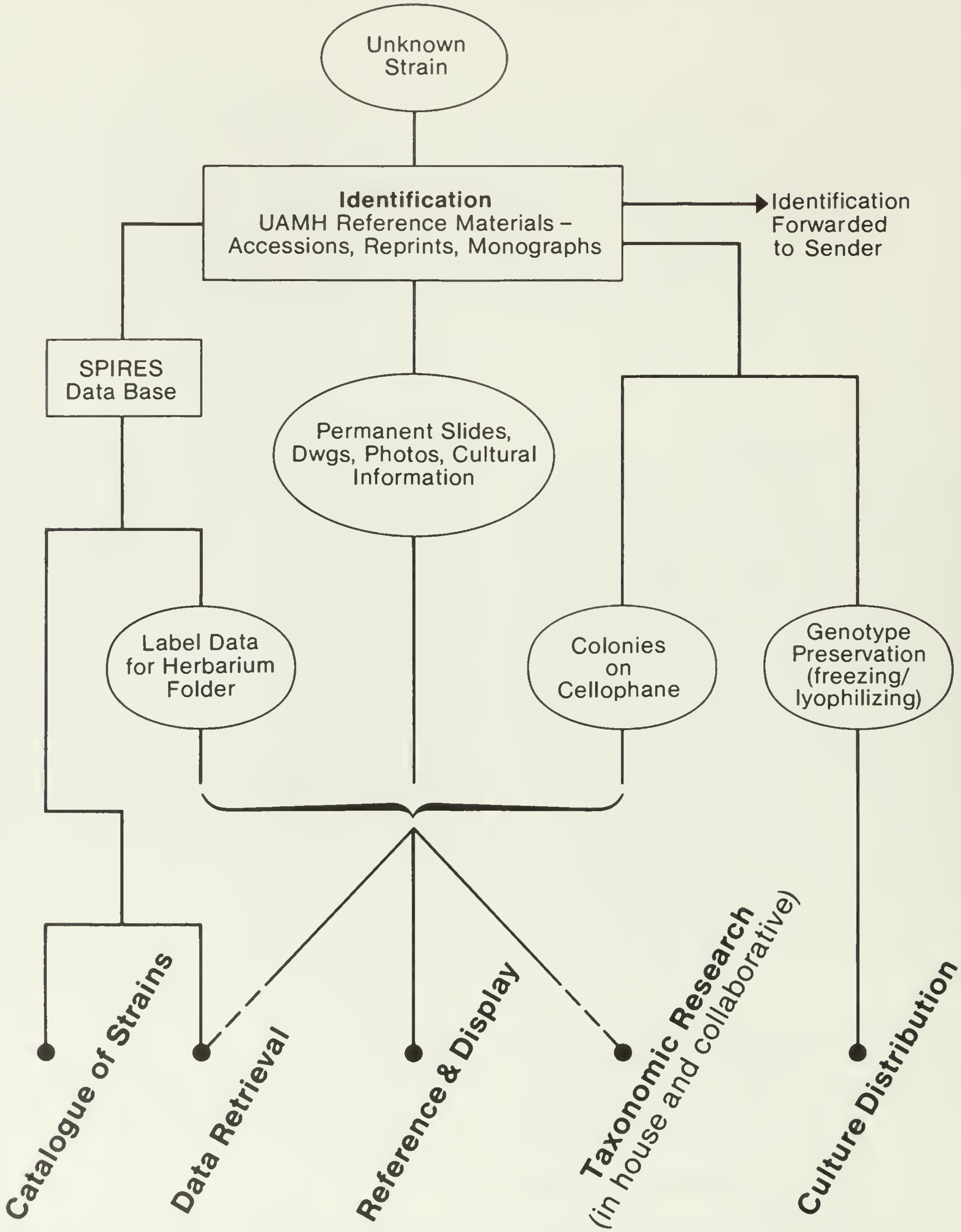
Unknown Strain
Identification
UAMH Reference Materials – Accessions, Reprints, Monographs
Identification Forwarded to Sender
SPIRES Data Base
Permanent Slides, Dwgs, Photos, Cultural Information
Label Data for Herbarium Folder
Colonies on Cellophane
Genotype Preservation (freezing/ lyophilizing)
Catalogue of Strains
Data Retrieval
Reference & Display
Taxonomic Research (in house and collaborative)
Culture Distribution

Fig. 1. Flow chart showing UAMH accession procedures.

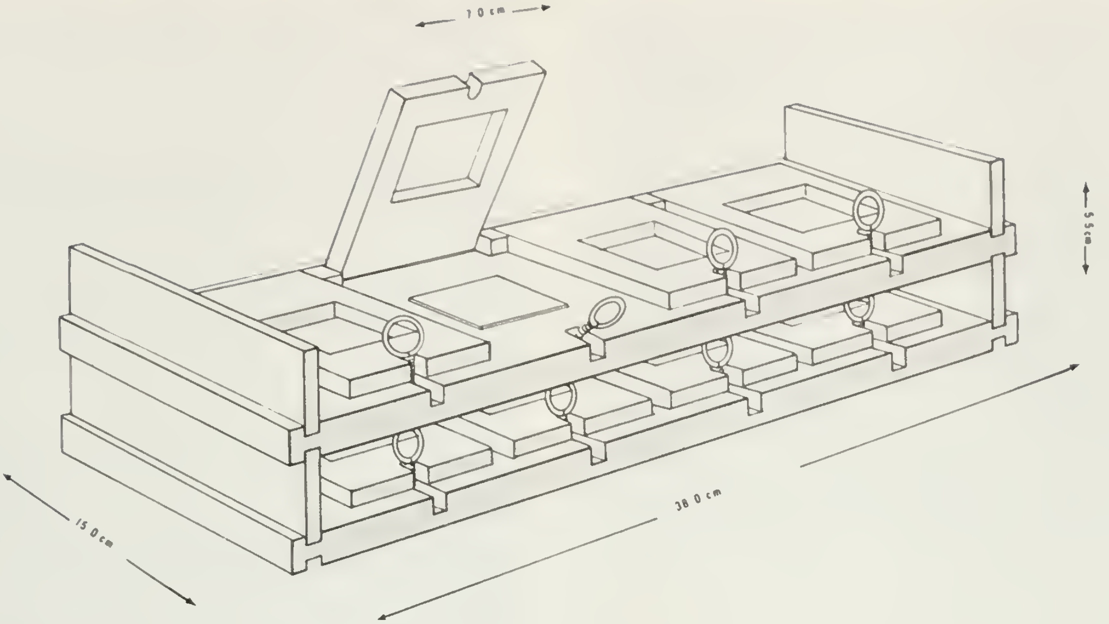

Fig. 2. Specifications and dimensions for apparatus used for mounting cellophane-backed colonies on cardboard frames.

as packets affixed to cardboard sheets 40 × 30 cm (16 × 12 inches) in size. This technique works reasonably well for large, tough specimens such as bracket fungi, but the technique is of limited usefulness for delicate specimens such as microfungi. At UAMH, colonies of microfungi are grown on a cellophane membrane layered onto a solid medium (Carmichael, 1963). Fungi are able to absorb nutrients from the medium through the cellophane membrane. When the colony is fully developed (usually after 2 to 3 weeks), the cellophane square is lifted from the agar medium and placed on the base of the press (Fig. 2). A bead of glue is placed around the perimeter of the window of a 9.5 × 7.5 cm cardboard frame and the frame is lowered onto the cellophane and clamped in place (Fig. 3). The colonies are air-dried under ultraviolet light for several days. The dried, mounted colonies are placed in polyethylene slip-cases, and stored in 20 × 13 cm herbarium folders, which are filed vertically in metal file cabinets.

Culture Preservation

Many fungi quickly degenerate in culture. For this reason, the most ideal method of preserving the genotype is one that arrests metabolic activity as much as possible. For some groups, lyophilization (freeze-drying) is an effective way of stopping metabolic activity without causing a loss in viability. Strains that can be lyophilized can be preserved indefinitely in sealed glass ampoules (Fig. 4).

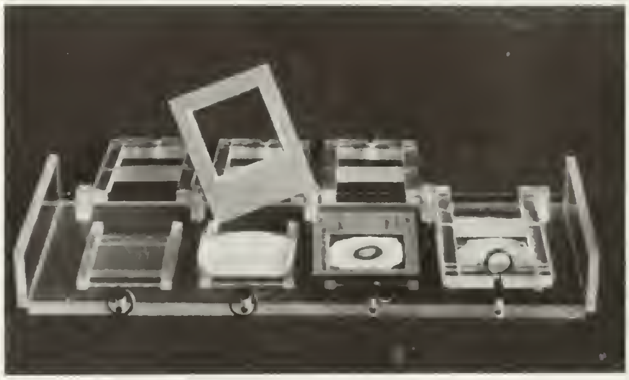

Fig. 3. Stages in the production of dried, mounted specimens.

UAMH also maintains strains on agar slants at −20°C. These are stored in easily accessible, vertical racks in a chest-type freezer (Fig. 5).

Data Base Management

The collection, maintenance, characterization, and distribution of cultures generate a great deal of data that must be organized into an efficient storage and retrieval system.

An on-line information retrieval system to maintain UAMH records has been established under SPIRES, which operates on the University of Alberta mainframe computer. SPIRES is ideally suited to storing data elements for large series of items (in this case, fungi). The

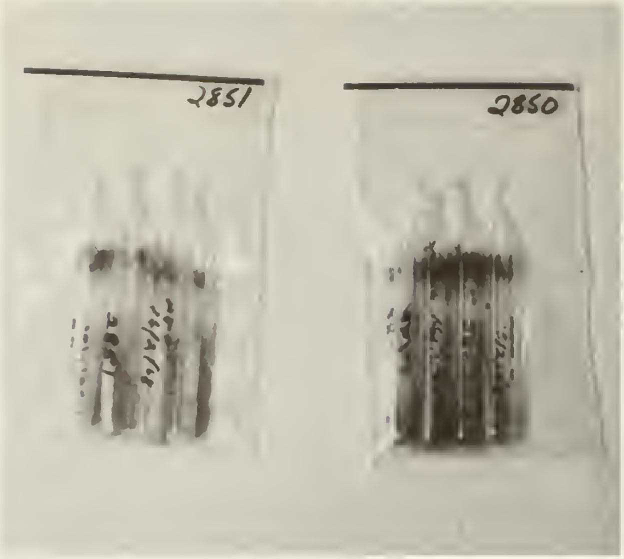

Fig. 4. Polyethylene packages containing lyophilized fungus strains in sealed ampoules.

SPIRES program offers "user-friendly" searching, updating, and output facilities and provides flexibility in safeguarding restricted information.

The UAMH data retrieval system facilitates routine record processing and allows for the generation of a catalogue of strains held in the collection. The data base consists of two subfiles—one containing information on fungus species and one containing information on fungus strains. The subfiles are explicitly linked by the data element "fungus species name". The data base allows for on-line, interactive searches for any species or strain held by UAMH. Key search elements are: species name, accession number, sender's name and number, incoming name, cross-reference numbers, and physiological properties. Information on strain characteristics is particularly useful to researchers since it allows selection of strains appropriate to particular research applications.

Routine record processing is facilitated through output protocols which generate herbarium labels and strain folders. The data base also provides for the production of annual reports, catalogues, and other statistical information.

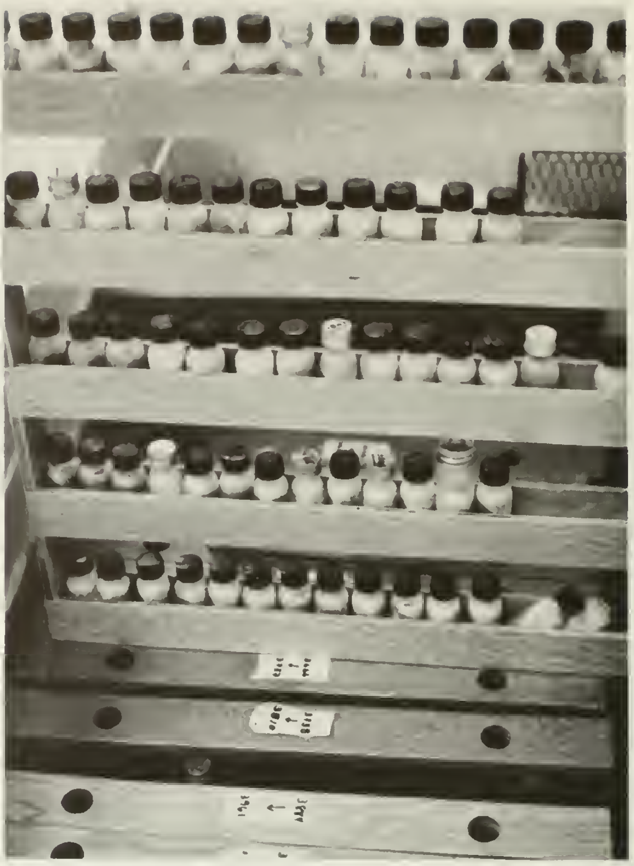

Fig. 5. Vertical freezer racks containing frozen slants of fungus strains in a chest-type freezer.

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DESIGN CONSIDERATIONS FOR COMPACT STORAGE

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ABSTRACT—Compact storage is a practical method of increasing storage capacity without adding floor area. Suggestions for floor plans and system design are discussed.

Introduction and Concept of Compact Storage

It is generally accepted that most people involved in the care and maintenance of collections have, at one time or another, considered making the storage area more efficient. Compact storage involves eliminating non-productive aisles in order to increase capacity or decrease the amount of floor space required (Fig. 1). The concept is becoming more acceptable as floor space becomes less available and more expensive, and as collections increase in size.

However, in the process of compacting storage, we must ensure that the stored material is not subjected to damage or deterioration. We must guard against fire, mildew, and overloading the floor, and at the same time make sure the collection is accessible to those who are working with it. When a good compact system is employed, there are, in fact, areas where protection of the materials is improved. When designing floor layouts in areas of compact storage, consideration should be given to the following.

LIGHTING

Ceiling lights should be arranged to run parallel to the floor tracks. This will ensure constant light in all moveable aisles. The number of lights, or their intensity, may have to be increased if the clearance between the top of the storage housing and the ceiling is less than 45 cm (18 inches).

AISLES

When deciding where the aisles will be located, ensure that the major access aisles and the moveable aisles are wide enough to manoeuvre the collection safely. If the material is stored in drawers, the aisle should be wide enough that any drawer can be opened completely, with a person standing in front of it to access the artifacts.

CARRIAGES, TRACK, FLOOR, AND RAMP

The carriages should be strong and light in construction (Fig. 2). Ensure that the carriage is designed to hold the anticipated weight. Long carriages are the most efficient, because short carriages require more aisles. Tracks (or rails) should be of steel, and should be installed perfectly level and parallel. Grout should be placed between the track and existing floor, to ensure a solid foundation. Make sure the wheels are of hardened steel and of as large a diameter as possible. Large wheels offer smoother, vibration-free carriage movement. Sealed wheel bearings prevent dirt from entering the bearing itself, and eliminate the need to add grease in the future. If the tracks are more than 12 mm high, a raised floor or deck should be considered. This decking creates a smooth floor with no obstructions for people or carts. Floor covering should be of tile or similar material; although carpets are warmer and more comfortable, they tend to collect dust and dirt. Maintenance should involve periodic cleaning of the track area with a light coat of oil or silicone applied to the track surface, to prevent rust.

Dust and water seals are available from some manufacturers. In many cases these seals are not very effective, since it is difficult to close the system tightly enough for the seal to function properly. Maintenance or servicing of the system should be possible without removing the cabinets or shelving from the carriage. All controls and moving parts should be easily accessible. Assuming the system is installed properly, and a normal run-in procedure is followed, there should be no need for a comprehensive or expensive maintenance program. The manufacturer should have spare parts available for emergency use, as well as factory-trained service people.

CABINETRY

In most cases, existing cabinets, shelving, or housing can be used in a mobile application. Some styles of cantilever shelving must be reinforced and strengthened before they can be mounted on moveable carriages. Cabinets with hinged doors should be tilted back slightly on the carriage. This will ensure that the doors are always closed before moving the system. Caution should be taken when anchoring double-walled or hermetically sealed cabinets together or to the carriage. The seal must not be punctured by the fasteners.

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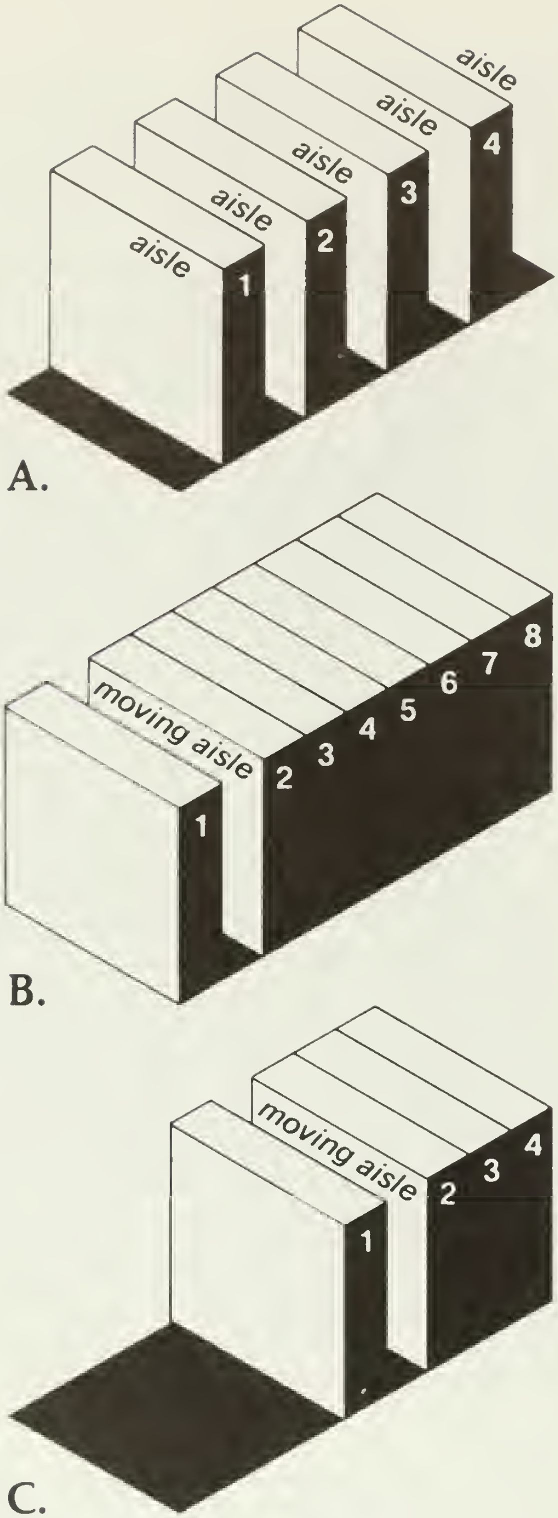

Fig. 1. Basic concepts of mobile shelving compared to conventional shelving systems:

A. Fixed storage shelves with multiple fixed aisles for access to stored materials.

B. Elimination of multiple aisles to one "moving aisle" allows 100% more storage capacity within the same space.

C. Conversion of the materials stored in A into half the space yields 50% saving of area for other work functions.

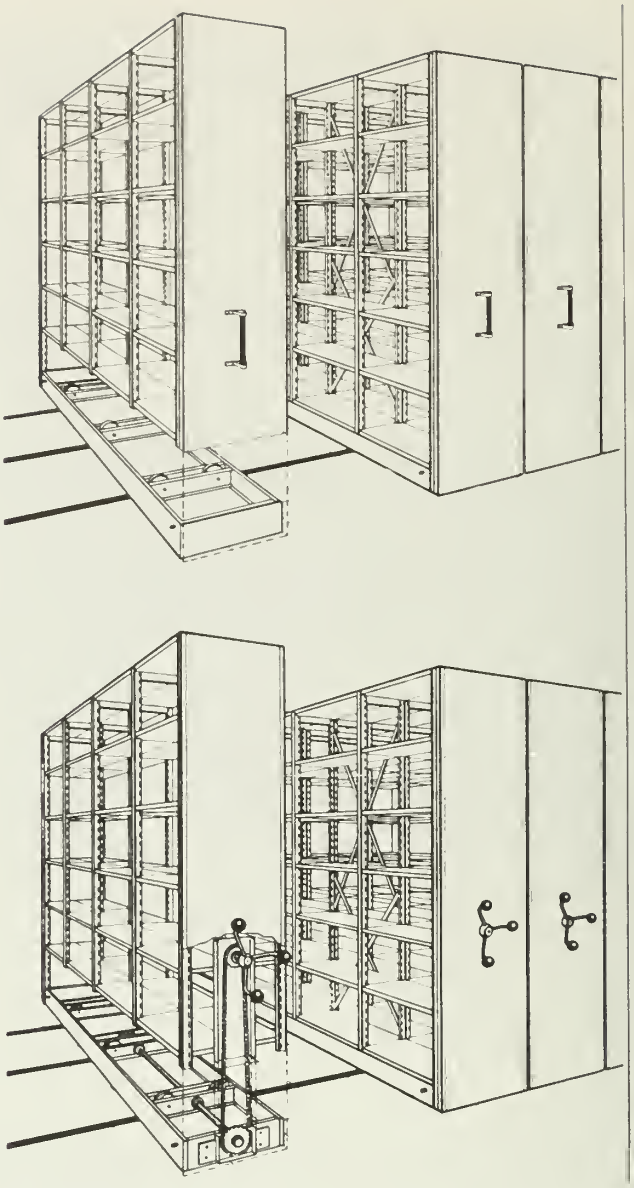

Fig. 2. Drive systems.

SYSTEM OPERATION

When the more space-efficient long carriages are used, the system, because of its weight, is best powered by electric motors. When motors are used, additional benefits are often achieved. Using electric power, the start-run-stop functions can be controlled. Carriage speeds should be slow and controlled, with no sudden stops and starts, and no bumping of one carriage to the next. Any such movement may damage the collection.

Safety systems can be readily incorporated in the design of electrically operated systems. For normal areas, safety sweeps or tapes are recommended. In this case the person accessing the aisle must kick the sweep or push on the tape to deactivate the system. Various other safety systems such as optical scanners, proximity switches, etc., are available. It should be noted that there are no proven automatic safety systems available for manual or mechanically assisted systems. However, when operating any mobile storage system, common sense suggests that the existing aisle should be checked for people or obstructions before activating the system.

Hand crank systems are considerably less expensive, and can move up to 45 tonnes with ease. Caution must be used to eliminate the bumping together of the carriages, which might cause collection damage.

FIRE PROTECTION

Consideration should be given to using a Halon gas system. Although expensive, it is the most effective means of fire protection. Halon gas contains no oxygen, and thus displaces the normal air in a given area, eliminating any chance of combustion. If Halon gas is not used, strict fire and smoking regulations should be enforced. Note that fire sprinklers should be removed from the collection storage area if possible, because in the case of a fire, water from the sprinklers will quite often do more damage than will the fire and smoke.

ASSISTANCE PROGRAMS

Before making the decision to change over to a mobile system, the financing of the project will have to be considered. The cost of a good system is not low, and the benefits the system will provide must be weighed carefully against the cost. Once you have resolved that for reasons of space, security, and an expanding collection, a mobile system is for you, how can you pay for it? The area of budgeting and fund raising is foreign to most people in collection management, and with good reason. You are more concerned with the general operation of your collection, and in many cases, are much too busy to concern yourself with fund-raising projects. However, it must be done by someone; the money will not come to you automatically. There are many sources of financial help. Federal, provincial, and local governments have funds available in the form of grants, loans, etc. (one example is the National Museums of Canada, Museum Assistance Programmes, Upgrading and Equipment Assistance Programme). Private industry should also be approached. It may take time and a certain amount of justification before these funds are made available, but it can happen.

The museum holds an important and unique place in any community. The community should take some responsibility for seeing that financial support is available to adequately house the museum's collection.

UNBUFFERED FORMALDEHYDE FOR LONG-TERM STORAGE OF LARVAL FISHES

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ABSTRACT—Larval fishes may be defined as the embryonic or post-hatching stages of fishes which lack complete complements of fin-rays and other morphological features characteristic of juvenile and/or adult fishes. Their bodies consist mainly of proteins, yolk materials, and developing cartilages. Most workers have recommended fixing larval fishes in 2–4% formaldehyde in water with short-term preservation and long-term storage in buffered 2–4% formaldehyde. I observed that many specimens stored for a decade or more in unbuffered formaldehyde were in better condition than those stored in buffered formaldehyde. Specimens stored in unbuffered formaldehyde possessed a variety of melanophores (mostly brown), firm but slightly shrunken bodies, and no signs of lysis (clearing); however, their bone and fin structures were impossible to stain properly with Alizarin Red S. Several biochemical reactions relating to fish proteins stored in unbuffered and buffered formaldehyde are discussed and compared. As a result of these observations and theoretical considerations, I recommend dilute unbuffered formaldehyde (2–5%) for the long-term storage of both marine and freshwater larval fishes in museum collections.

CONTAINERS AND CONTAINMENT

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ABSTRACT—A review of practices in the maintenance of wet collections is presented. Without basic items of superior quality, a high percentage of operating funds and staff time are spent on the continuous monitoring of collections. The major problem appears to be the unavailability of jars, vials, and other containers designed specifically for collection uses. In addition, poor quality control in production and continuing design changes cause problems. The approaches taken at the Invertebrate Zoology Division, National Museum of Natural Sciences, are outlined. A proposal is put forward for acquiring containers from a single source, as well as other recommendations for improving existing procedures.

A SPOT TEST FOR DISTINGUISHING FORMALIN FROM ALCOHOL SOLUTIONS

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ABSTRACT—Formalin and alcohol are routinely used as preservatives for biological specimens in museum collections and biological and medical laboratories. In some cases the identity of the preservative fluid that a specimen is contained in is not known, but must be discovered before the specimens can be transferred to an appropriate permanent preservative.

The traditional method for distinguishing between formalin and alcohol solutions has been to sniff the preservative. Because formaldehyde is irritating, toxic, and probably carcinogenic, a safer test for distinguishing formalin from alcohol was developed.

The test employs strips of filter paper containing an acid/base indicator and a mixture of sodium sulphite and sodium metabisulphite. These test strips respond rapidly to aqueous formalin solutions containing more than about 1.5% formalin by changing colour from yellow to red. They will not respond to the low levels of formalin that are present in most alcoholic preservative fluids from prior fixation in formalin, and hence will rapidly distinguish formalin solutions from alcohol solutions.

The test strips are inexpensive and simple to make and to use.

Introduction

Formalin and alcohol are routinely used as preservatives for biological specimens in museum collections and medical and biological laboratories. Frequently specimens are initially fixed in a 5% or 10% solution of formalin in water, then washed in water and transferred to 40 to 75% ethanol or isopropanol. Per cent formalin is used in this paper to mean per cent, volume by volume, of standard 37 weight per cent (40 volume per cent) formaldehyde solution in the specified solvent; per cent of alcohol means per cent, volume by volume, of alcohol in water. For recent, staff-collected specimens, the kind of preservative the specimens are currently stored in is known, but in the case of specimens donated by other museums, collectors, or biological investigators, or held in old, uncatalogued lots, the identity of the preservative is often not known. The nature of the preservative must be discovered before the specimens can be transferred to the appropriate permanent preservative.

The time-honored method for distinguishing between formalin, isopropanol, and ethanol solutions has been to sniff the preservative. This test has several disadvantages:

1) The acuity of the nose declines after sniffing several samples, until one is unable to identify any further samples.

2) Formalin and isopropanol, and even ethanol to some people, are disagreeable to smell. Formaldehyde irritates the nose and eyes and causes them to water. If the specimens are poorly preserved, or are in strong formalin, the test will be even more disagreeable.

3) Formalin and isopropanol are toxic. The inhalation of formaldehyde and isopropanol can be expected to stress the body and to impose a load on the liver. Some people develop allergic responses to formalin. Inhalation of formaldehyde causes irritation of the mucous membranes and can cause cough, dysphagia, bronchitis, pneumonia, edema or spasm of the larynx, and, uncommonly, pulmonary edema (Gosselin, et al., 1976). Perera and Petito (1982) reviewed the scientific literature pertaining to the possible carcinogenicity of formaldehyde and concluded that for practical purposes formaldehyde should be considered to be carcinogenic. More recent studies have supported this conclusion (F. Perera, pers. comm., 1985).

For the above reasons it is desirable to reduce exposure to these substances to a minimum. However, for an alternative to the olfactory test to be effective it must satisfy a number of requirements. Criteria for an acceptable test include:

1) It must clearly distinguish between formalin and alcohol solutions.

2) Alcohol solutions containing trace amounts of formaldehyde must not be confused with formalin solutions.

3) It must be non-toxic and non-irritating.

4) It must be simple to use. Most users would not bother with complicated tests. The test should be immediately understandable to technicians, students, and volunteers with no background in chemistry.

5) It must be quick. Slow test methods would interfere

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with efficient work flow in the lab.

6) It must not adversely affect the specimens or require use of a large amount of the preservative.

7) It must be inexpensive. Most museums have modest budgets.

Method

The requirements for speed and simplicity are satisfied by the use of a test employing suitably treated strips of paper that change colour on exposure to formalin.

There are numerous methods available for both the qualitative and quantitative analysis of formaldehyde (Walker, 1975). The method chosen for adaptation to strip testing was the sodium sulphite (Na_2SO_3) method of quantitative analysis. This method is based on the reaction of formaldehyde with sodium sulphite to form the formaldehyde-bisulphite addition product and sodium hydroxide:

$$CH_2O_{(aq)} + Na_2SO_3 + H_2O \rightarrow CH_2(NaSO_3)OH + NaOH$$

The hydroxide produced can be detected by an acid/base indicator. This reaction is rapid at room temperature, requires only solid reagents, is relatively specific for formaldehyde, and hence is well suited to being used as a basis for a paper strip test for formalin.

Two factors influenced the choice of the indicator to be used: 1) the pH transition range must be beyond the pH ranges encountered in buffered preservative fluids yet be within the range that the test reaction can produce; 2) The colour change must be readily discernible, preferably even for colour-blind people. Both of these requirements are satisfied by 5-(4-nitrophenylazo)salicylic acid, also known as either Alizarin Yellow R or Mordant Orange 1. Its pH transition range is 10.1 to 12.0 and the colour change from the acid to the base form is yellow to red (Weast, 1976).

The use of sodium sulphite as the test reagent produced test strips that were too sensitive. They gave a full response to solutions of less than 0.5% formalin in 50% isopropanol. Since many preservative fluids that are essentially alcohol solutions contain varying amounts of

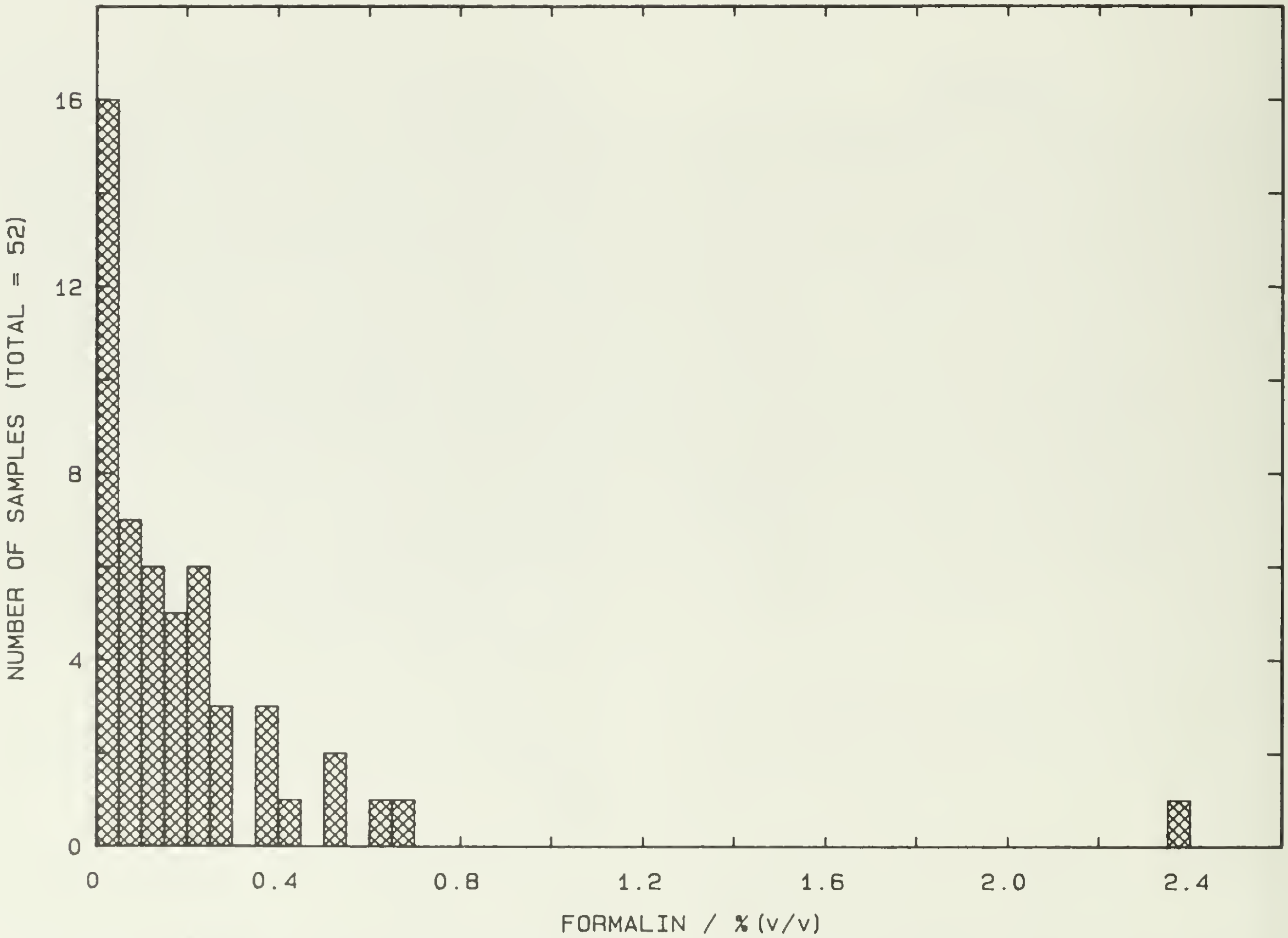

Fig. 1. The distribution of formalin concentration in 52 random samples from the National Museum of Natural Sciences Ichthyology Collection.

Table 1 Approximate ranges of sensitivity for test strips made with a 0.70 M Na_2SO_3 and 0.15 M $Na_2S_2O_5$ solution

Solvent	Percentage Formalin Concentration That Shows:	
	Negligible Response	Full Response
Water	0.5	1.4
50% Isopropanol	0.5	2
75% Ethanol	1.5	4

residual formaldehyde from the fixing process, these strips could not distinguish what was essentially a formalin solution from what was essentially an alcohol solution. To determine what level of formalin concentration should be used to differentiate a formalin solution from an alcohol solution, the formaldehyde concentration in 52 samples chosen at random from the National Museum of Natural Sciences Ichthyology Collection was determined. The results are given in the form of a histogram in Figure 1. The highest concentration, 2.38%, was found to be a formalin in water solution containing no alcohol. Consequently, all specimens in alcohol solutions contained less than 0.7% formalin and hence, 1% would be a reasonable level to distinguish between formalin and alcohol solutions.

The sensitivity of the papers can be most easily varied by replacing some of the sodium sulphite with sodium metabisulphite ($Na_2S_2O_5$). A formulation using 0.7 M Na_2SO_3 and 0.15 M $Na_2S_2O_5$ provided the range of sensitivity shown in Table 1.

Materials

1) Filter paper sheets 46 × 57 cm, medium porosity
2) 5-(4-nitrophenylazo)salicylic acid
3) Sodium sulphite
4) Sodium metabisulphite
5) Ethanol

All materials are available from laboratory suppliers.

Procedure

Producing the test strips simply involves impregnating sheets of filter paper—first with the indicator solution and secondly with a solution of the test reagents. Following impregnation, individual strips are cut from the sheets. Figure 2 is a schematic illustration of a filter paper sheet as it will appear following the second impregnation step, that is, when being unrolled during step 7 of this procedure. Exact dimensions are not important, but those given here were found to give satisfactory results. The procedure is as follows:

1) Cut filter paper sheets into 11 × 57 cm sheets.

2) Tightly roll a single 11 × 57 cm sheet lengthwise onto a section of glass tubing. Tubing having a diameter of 2 to 3 cm is a convenient size for this. Apply transparent tape to completely cover the bottom 5 cm of filter paper.

3) Place the taped end of the roll into a solution containing 0.5 g of the indicator 5-(4-nitrophenylazo)salicylic acid per 100 ml of 95% ethanol.

4) When the indicator has risen 4 to 5 cm in the paper remove the tape and unroll the sheet. Set the sheet aside to dry. To ensure consistency among the finished test strips it is important that, while it is drying, the sheet should be in a position such that no area of the sheet touches another area of the sheet.

5) When dry, roll the sheet again, in the same manner as was done in Step 2, and tape over the bottom 2 cm.

6) Dip the roll into the test reagent solution until the solution has risen about 2 cm in the paper. The test reagent solution is prepared by dissolving 8.8 g Na_2SO_3 and 2.9 g $Na_2S_2O_5$ in 100 ml water. This solution should be prepared the same day as the strips are made.

7) Unroll and spread the sheet and place it in an oven at 50°C until dry (approximately 30 minutes). Again, as in step 4, it is important to ensure that no part of the sheet is contacting another part of the sheet while it is drying.

8) Cut the sheet to make the finished test strips approximately 11 cm × 0.5 cm.

9) Store the finished strips in a well-sealed container together with a desiccant. Indicating "Drierite" is a convenient and effective desiccant for this purpose.

Interferences

Aldehydes other than formaldehyde will react to some extent with these test strips. However this is not considered a problem since higher aldehydes might be expected to exist as impurities in formalin solutions, but not in any significant amount as impurities in alcohol.

Ketones show, to a limited extent, a reaction with the test strips. Volume per cent solutions of acetone in water gave the following responses:

5%—negligible
10%—trace response (response ≅ 0.6% formalin)
20%—¼ response (response ≅ 1% formalin)

The responses, in addition to being minor even at high acetone concentrations, appear more muted and more transient than equivalent responses to formalin solutions.

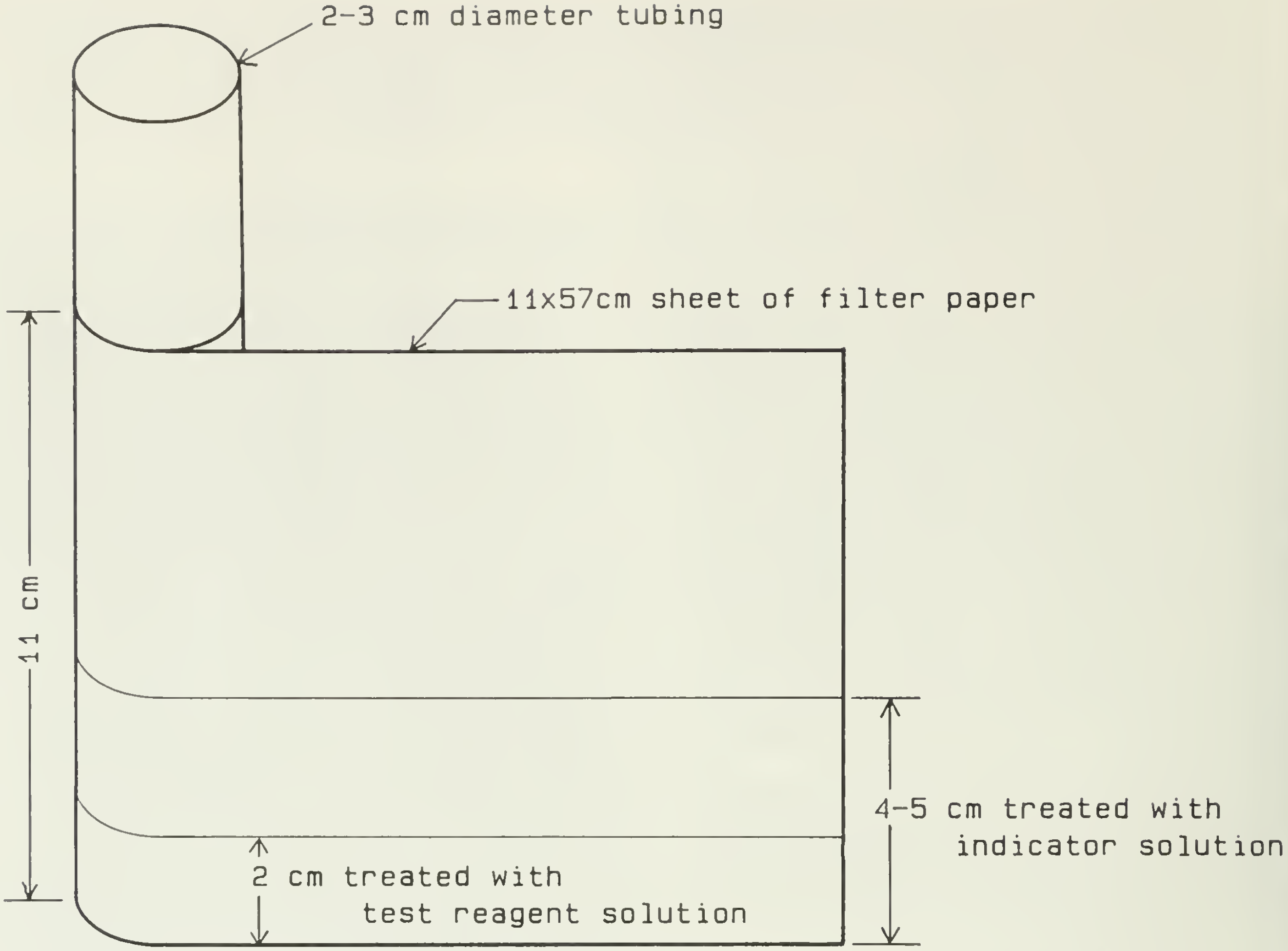
2-3 cm diameter tubing
11x57cm sheet of filter paper
11 cm
4-5 cm treated with indicator solution
2 cm treated with test reagent solution

Fig. 2. A schematic illustration of a filter paper sheet after impregnation with the indicator and the test reagent solutions.

Since this test measures formaldehyde indirectly through a change in pH, pH and total titratable acidity or alkalinity may affect or even nullify the validity of the response.

The total quantity of acid or alkali present is more significant than pH in its effect on responses. The test strips were found to be capable of distinguishing between solutions that were 5% and 0% formalin in water throughout the pH range of 1.3 to 12.4. This rather wide range applies only when strong acids or alkalies are the sole sources of titratable acidity or alkalinity.

Because acidity and alkalinity encountered in preservative solutions will more likely be due to the presence of weak acids and bases, the effect on response is more a result of the quantity of acid or base present rather than the pH of the solution.

For example, 6 g/l of sodium carbonate added to a 0.5% solution of formalin in water resulted in a pH of 11.2 but did not noticeably affect the response of the test strips. The addition of 150 g/l to a 0.5% solution of formalin in water resulted in a pH of 11.3, a difference of only 0.1, but changed the response of the test strips from negligible to three-quarters full. Fortunately, buffers are not added in such high concentrations, and are generally not as alkaline as sodium carbonate. These facts suggest that the presence of a buffer of the type, and in the quantity, likely to be employed in preservative solutions will not interfere with the response of the test strips. The response of the test strips to the following published formulations (McAllister, 1965) for buffered fixative solutions was tested.

10% formalin + 2.6 g/l borax
14% formalin + 14 g/l hexamine
16% formalin + 3% concentrated ammonium hydroxide
5% formalin + excess calcium carbonate
40 g/l paraformaldehyde + 10 g/l sodium carbonate

The test strips gave immediate positive responses to all of these solutions.

It is clear from the discussion above that the effect of alkalinity in a solution being tested is to make the strips more sensitive to formaldehyde than they would be otherwise. In solutions that are extremely alkaline, the treated part of the test strips may undergo a complete colour change even in the absence of formaldehyde. It is for this reason that a section of the test strip is treated with indicator only and not with the other test reagents. A test that shows a colour change only in the section of the test strip treated with indicator alone indicates that the solution being tested is strongly basic but contains a negligible (by definition) amount of formaldehyde. An example of a solution that would show this response is a 1% (w/v) solution of trisodium phosphate in water. Extremely alkaline solutions may cause both the reagent plus indicator and indicator alone sections of the test strips to undergo a colour change. If this occurs a sample of the solution must be made less alkaline before the strip test can be employed.

The effect of excess acidity is to reduce or, in extreme cases, to eliminate the response of the test strip to formaldehyde. In order to determine whether or not acidity levels in preservative solutions are high enough to be of concern, 52 samples of nominal 45% isopropanol preservative chosen at random from the National Museum of Natural Sciences Ichthyology Collection were titrated with N/10 NaOH to a phenolphthalein endpoint. The results, expressed in milliequivalents per litre (meq/l), are given in Figure 3. The highest value found was 31.4 meq/l. The response of the test strips was checked in solutions containing 5% formalin and 100 meq/l hydrochloric acid. The test strips gave an immediate response to this solution if water was the solvent, but in 70% ethanol 5 minutes was required for the full response to develop. The same solution in 50% isopropanol produced a full response in 30 seconds. The times given here were recorded for strips stored over a desiccant. Test strips in equilibrium with a higher relative humidity were faster to respond, but as discussed later the test strips have a greatly reduced shelf life when stored at higher relative humidities, and hence,

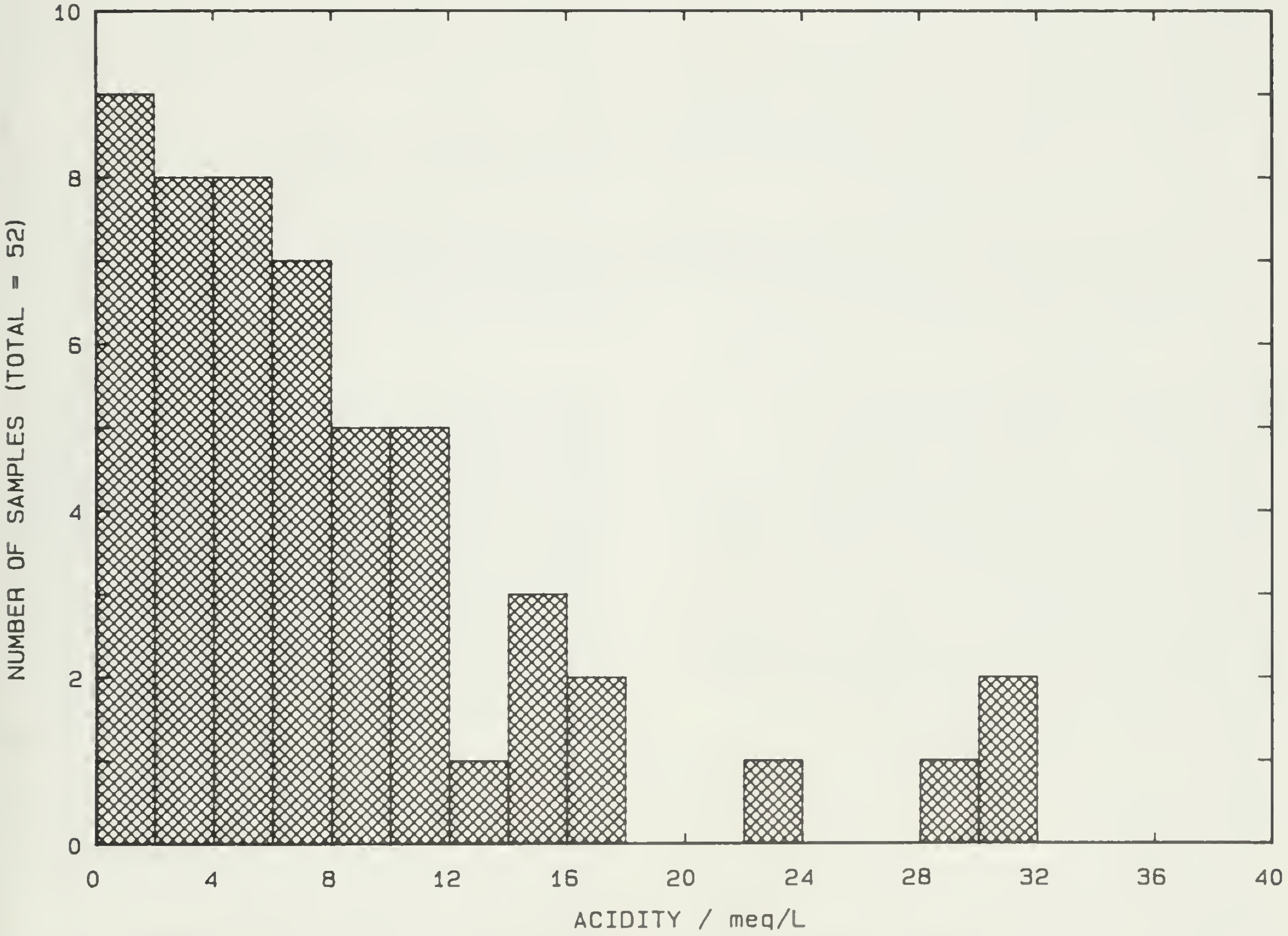

Fig. 3. The distribution of acidity in 52 random samples from the National Museum of Natural Sciences Ichthyology Collection. Determined by titration to the phenolphthalein end point.

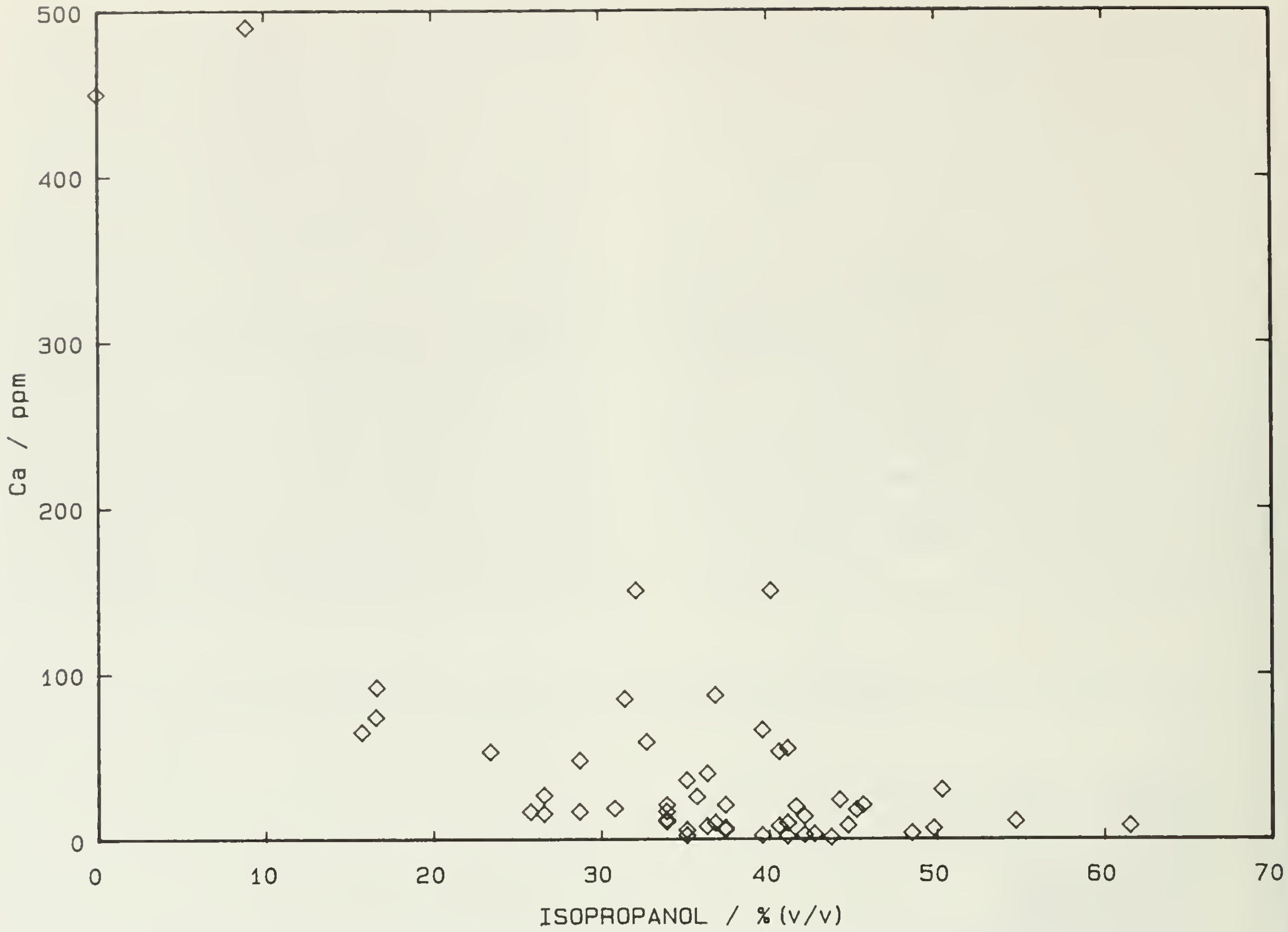

Fig. 4. The distribution of dissolved calcium concentration as a function of isopropanol concentration in 52 random samples from the National Museum of Natural Sciences Ichthyology Collection.

should be stored, and probably would be used, in a desiccated state.

Cations that form insoluble sulphites constitute another possible interference. Calcium and iron are the only such cations that would be expected to be present in preservative solutions in significant quantities. The 52 solutions used for other tests were analysed for calcium and iron by atomic absorption spectroscopy. Iron was present only as a trace impurity. The median iron concentration was 55 ppb and the maximum was 2.5 ppm, consequently iron is unlikely to be a cause of interference.

Calcium, on the other hand, was present in significant amounts. The calcium concentrations are shown plotted against isopropanol concentration (from density determinations) in Figure 4.

It is clear that calcium concentration declines with increasing alcohol concentration. This is fortunate since, as with level of acidity, high calcium concentrations are most significant as an interference when alcohol concentrations are high. For example, 1500 ppm Ca added to a 5% solution of formalin in water had no effect on the response of test strips. On the other hand, 200 ppm Ca added to a solution containing 5% formalin in 75% ethanol changed the time for full response from 15 seconds to 2.5 minutes. In general, calcium is not likely present in sufficient concentrations to seriously affect the response of test strips to purely aqueous solutions of formalin. For example, a 5% formalin in water solution stirred vigorously for three weeks with a large excess of powdered calcium carbonate continued to give a full and immediate response. Calcium is probably a significant interference in some cases when the solution being tested contains both formalin and alcohol, but a meaningful assessment of its significance as an interference cannot be made without data from more analyses performed on a wider variety of preservative fluids.

To summarize, interferences are unlikely to result in a 5% or 10% solution of formalin in water with or without buffers ever failing to give a full response to the test strips. In the case of alcoholic solutions, interferences will sometimes cause the response to be greatly delayed, but in all cases so far investigated, a response eventually will be generated if the concentration of formalin is 5% or greater.

Shelf Life

Sodium sulphite, in the presence of atmospheric moisture, is oxidized to sodium sulphate. This fact limits the shelf life of test strips exposed to the atmosphere. Test strips stored at 85% relative humidity gave unsatisfactory responses after 15 days. The shelf life for test strips stored in the absence of atmospheric moisture is as yet undetermined. Test strips stored in a jar together with indicating "Drierite" have shown no deterioration for, at the time of writing, 14 months. It is probable that under these conditions there is practically no limit to shelf life. Significantly, aging of the test strips at any relative humidity does not change the sensitivity of the strips, but simply mutes the colour response. This fact makes it possible to check the viability of a supply of test strips simply by immersing one of the strips in a stock formalin solution to determine whether or not the response is readily detectable.

Use

Test strips should be stored in a well-sealed container together with a small amount of a desiccant. To use, insert the yellow end of a strip into the solution to be tested. The time that the strip is in the solution should be kept as brief as possible. Less than a second is required to wet the strip. Responses in the various solutions that are likely to be encountered are given in Table 1.

Solutions not containing alcohol will usually show the appropriate response within 10 seconds. Depending on the quantity of interferences present, solutions containing 75% ethanol may require as long as 5 minutes for the appropriate response to develop. In many cases this will permit the distinction between aqueous formalin solutions and alcohol solutions containing residual formalin.

If the yellow portion of the test strip above the 2 cm sulphite-treated portion turns red then the solution is too strongly alkaline (pH>12) to be tested without prior neutralization.

Discussion and Conclusions

A simple and inexpensive paper test strip has been developed that will distinguish between formalin-based fixative solutions and alcohol solutions containing traces of residual formalin. This distinction is readily apparent within seconds of wetting the test strip. The test was not developed to provide a quantitative determination of the amount of formalin in alcohol. The results obtained during testing do, however, suggest that semi-quantitative results for the quantity of formalin in alcoholic solutions might be obtainable if the type and concentration of the alcohol present is known. The further development of this test to make it capable of rendering semi-quantitative results reliably and within a short time (less than one minute) would require solutions to the combined problems of limited solubility and interference from acidity and dissolved calcium. These problems can only be solved when data on the alcohol, formalin, acidity, and calcium concentrations of fluid preservatives in a variety of different collections is available.

Acknowledgements

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THE EFFECT OF A COMPUTER ON THE PHILOSOPHY OF (MY) COLLECTING

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ABSTRACT—It is probable that in the future museums will have more in common than a collection of some sort—they will have a computer. The computer is an extremely powerful tool for managing the information inherent in any kind of collection. As shown by experience at the UBC Geological Museum, a computer system brings with it more than the advantages of an elaborate card catalogue.

The Geological Museum at UBC is staffed by one person, and a computer system aids in all aspects of museum operation. It is used for: 1) data retrieval, 2) cataloguing, 3) label generation, 4) writing, and 5) gift shop operation. The computer has made it possible for one person to manage all of the above functions without excessive expenditure of time. In fact, the efficiency of the computer has generated revenue over and above the cost of operation. This presentation will review these applications, especially with respect to data retrieval from a mineral collection.

The use of the computer for collections management makes the development of a written collections policy very useful. Such a policy represents a goal, and success in attaining this goal can be examined quantitatively. A good management system makes it possible to discover not only what a collection contains, but also what it needs, and how well these needs are being filled. In addition, it is also possible to validate the original collecting policy by tracking the use of the collection.

There are certainly great differences between various disciplines and between different museums. The computer can be useful in all these contexts, but it may find its greatest utility in the small museum, where it can facilitate many museum functions, despite limited staffing and budget. Funding sources, especially governments, are forcing museums to do more with less, and computer applications give them one way of coping with that reality.

INDUCED COLOUR FADING IN ENTOMOLOGICAL SPECIMENS

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ABSTRACT—Colour fading of entomological specimens was quantified using the Munsell colour measurement technique. Thirty-three specimens were subjected to ultra-violet radiation in the 300 to 400 nanometer range. Colour measurements were taken at regular intervals. Yellow specimens were "colour-fast" and showed little change in hue whereas all other changes in hue were towards yellow. The colour change was maximal among the blues or reds with these colours shifting towards yellow early in the experiment. Under conditions of high humidity greater colour change was noted among iridescent than non-iridescent specimens. Under these experimental conditions a physical change probably took place thereby altering structural colour. Changes of value were small, usually a lightening in non-iridescent specimens but a darkening in iridescent specimens. Chroma measurements indicated that all specimens became duller throughout the experiment.

Introduction

The fading effect of light on artifacts and specimens is regarded as a significant problem in museum exhibits. Following a recent temporary natural history display at the Manitoba Museum of Man and Nature, it was found that some specimens had yellowed and faded much more than others. Botanical specimen colour had shifted dramatically, as was evident when the exhibit specimens were compared with duplicates from storage. The colour had faded somewhat and had yellowed. These findings are similar to those of Feller (1964) and Lusk (1975) who noted that the plant dyes of some artifacts reacted almost immediately with light.

An equally impressive record of colour change was found on comparison of a faded moth specimen, which had served as a curio wall-hanging for 40 years, with its siblings which had been stored in the darkness of museum cabinets. Again, yellowing was evident as was a significant degree of lightening or fading and some dulling had occurred.

Bearing these examples in mind, a simple experiment was designed to investigate colour fading in entomological specimens. Of special importance was the fact that the colour of some insect specimens, for example iridescent tropical butterflies, is based on physical structure, rather than pigmentation. The "fastness" of both pigment and structural colour was of interest, since Giles (1966) noted organic colouration was fugitive whereas structural colour was usually permanent.

Materials and Methods

The experimental procedure used to study colour fading in entomological specimens involved thirty-three pinned specimens. The specimens (Fig. 1) were selected to cover a range of colour based on both physical and chemical colouration. These were subjected to ultra-violet radiation supplied by a Sylvania F15T8-BLB light. This light source was selected as it was readily available, relatively mild, and yet provided a source of high-energy radiation in the 300 to 400 nanometer range known for increasing photochemical reaction (Thomson, 1978), thereby reducing experimental time. In addition, the radiation was applied continuously to further speed the experiment. Specimens were placed approximately 15 cm from the light.

The apparatus (Fig. 2), consisting of the light, a simple household humidifier, a Model 5020 H-1-Q Weathertronic™ seven-day hygrothermograph, and the specimens, was housed in a hood of plastic film designed to reduce temperature fluctuation and maintain, when desired, higher than ambient humidity, since the latter has been shown to be related to the rate of fading (Thomson, 1978). The experiment ran for 120 days of which 60 were at high humidity.

Colour measurements were taken using the Munsell System at specific locations on the specimens prior to UV light exposure and thereafter at routine intervals. This colour system is based on the three-dimensional colour tree with the axes hue, value, and chroma corresponding to the psychological attributes of colour hue, light or dark, and dull or bright. Designations of colours are given in the order hue, value, and chroma. For example, 2.5RB 4/6 indicates a colour of 2.5 red-blue hue, 4 value, and 6 chroma. The Munsell System is based on matching the colour of specially prepared chips with that of the specimen and requires very specific conditions of illumination and viewing procedure as described in McKillop

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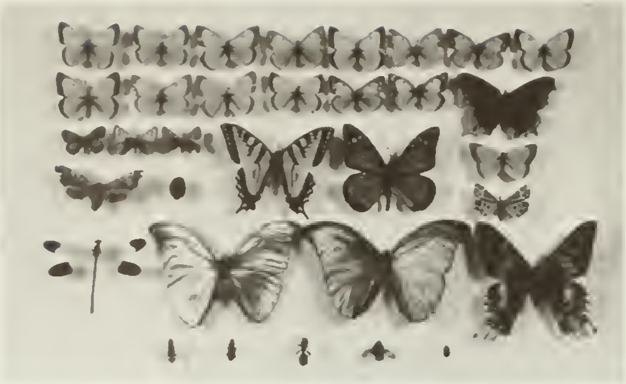

Fig. 1. Specimens prior to treatment.

and Preston (1981a). The colour measurement technique described in that paper was used throughout. It should be noted that through visual interpolation upwards of 100 000 different colours can be quantitatively described.

Results and Discussion

Table 1 presents the pre- and post-treatment colour of the various specimens as well as the change in colour. The specimen arrangement is based on hue, with reds (2.5R) at the top of the listing and red-purples (10RP) at the bottom. This arrangement parallels that in the Munsell Book of Colour.

Experimental fading results indicated that changes in hue showed a movement of the reds towards yellow, a negative change (−ve); green-yellow towards yellow, a positive change (+ve); blue towards green-yellow (+ve); and purple-blue and red-purple towards yellow (−ve). Thus overall changes were towards yellow, in keeping with the well-known fading or yellowing phenomenon. In general yellow specimens were "colour fast" and showed little change in hue whereas maximum yellowing occurred among those spectral colours furthest from yellow. It appeared that light systematically destroyed the light-sensitive portions of the original colour leaving only those that were more colour-fast.

Most interesting was the shift towards yellow from positive to negative that occurred between blue and purple-blue. Hence, not only did this experiment quantify the yellowing effect, but it also indicated that the hue of a blue specimen yellowed through the greens (a positive change), whereas a purple-blue specimen yellowed through the reds (a negative change). This shift in movement towards yellow is probably associated with the spectral wavelength of the specimens' original colours, and thus those hues of longer wavelengths moved negatively, whereas those with shorter wavelengths moved in a positive manner. Interestingly, purple-blue and red-purple are undefined colours, as they have no spectral equivalent (Thomson, 1978), and may more closely approximate long wavelength reds rather than the short wavelength blues. This affiliation of purple-blue and red-purple to red rather than blue is thus not necessarily an aberration.

Changes of value were generally small and usually indicated a lightening in non-iridescent specimens, but a darkening in iridescent specimens. Only two specimens showed a positive change in chroma; all other changes were negative, indicating an overall tendency for specimens to dull. The two that showed a brightening were beetles and these looked somewhat greasy upon comple-

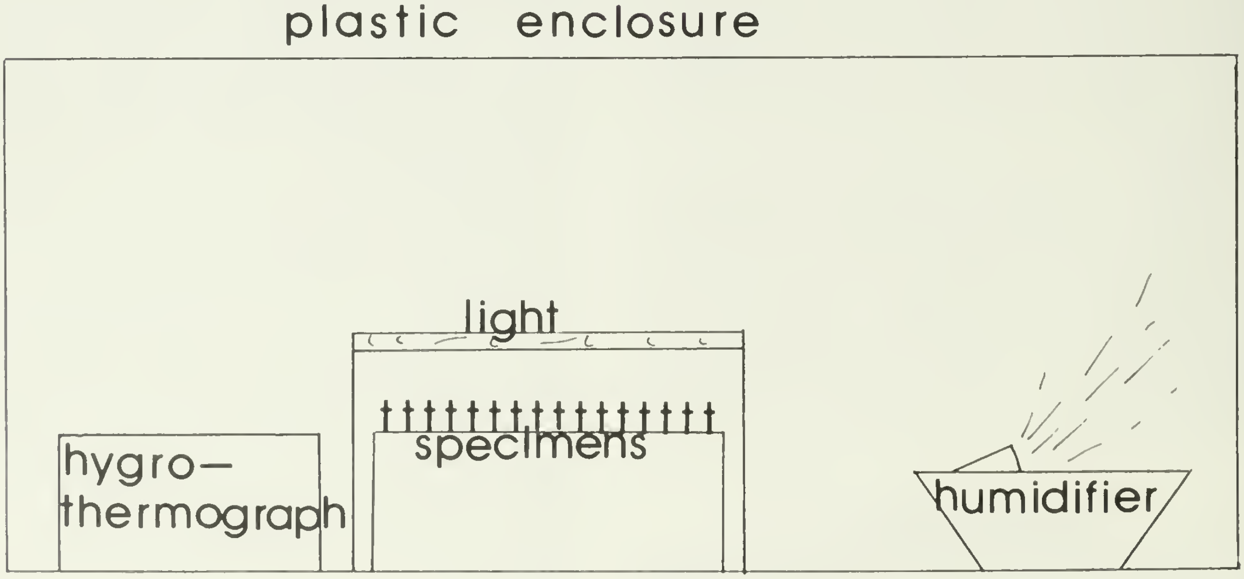

Fig. 2. The apparatus.

Table 1 Colour change for various test species

Test Species Name	Pre-treatment Colour	Post-treatment Colour	Colour Change		
			△H	△V	△C
Smerinthus jamaicensis ◀	2.5 R 5/8	2.5 YR 8/2	−10	+3.0	− 6
Smerinthus jamaicensis ◀	2.5 R 4/8	10 YR 8/2	−17.5	+4.0	− 6
Pterostichus melanarius	2.5 R N1/N	2.5 R N1/N	0	0	0
Apantesis virgo ◀	2.5 YR 7/8	2.5 Y 8/2	−10	+1.0	− 6
*Dasymutilla occidentalis**	2.5 YR 5/11	2.5 YR 4/8	0	−1	− 3
Nymphalis antiopa	2.5 YR 1.5/4	2.5 YR 2/2	0	+0.5	− 2
Colias eurytheme	7.5 YR 7/12	7.5 YR 7/10	0	0	− 2
Phycoides tharos ◀	7.5 YR 5/10	7.5 YR 7/6	0	+2	− 4
Danaus plexippus	7.5 YR 5/10	7.5 YR 5/8	0	0	− 2
Silpha americana	7.5 YR 4/4	7 YR 4/6	+ 0.5	0	+ 2
Lycaena helloides ◀	8 YR 6/8	2.5 Y 8/2	− 4.5	+2	− 6
Cicindela formosa	10 YR 8/4	10 YR 8/6	0	0	+ 2
Lycaena helloides ◀	10 YR 7/6	2.5 Y 8/2	− 2.5	+1	− 4
Agrion aequabile	10 YR 3/4	7.5 YR 3/4	+ 2.5	0	0
Colias eurytheme	1.5 Y 8/12	2.5 Y 8/10	− 1	0	− 2
Agrion virgo	2.5 Y 8.5/3	2.5 Y 8/2	0	−0.5	− 1
Colias eurytheme	2.5 Y 8/10	2.5 Y 8/8	0	0	− 2
Papilio glaucus	5 Y 8/7	2.5 Y 8/2	+ 2.5	0	− 5
Colias philodice	10 Y 8.5/8	10 Y 8/6	0	0	− 2
Colias philodice	10 Y 8.5/7	10 Y 8.5/7	0	0	0
Colias philodice	10 Y 8.5/7	10 Y 8.5/6	0	0	− 1
Colias philodice	10 Y 8/6	10 Y 8.5/5	0	+0.5	− 1
Colias philodice	1 GY 8.5/8	10 Y 8.5/7	+ 1.0	0	− 1
Colias philodice	1 GY 8.5/6	10 Y 8.5/6	+ 1.0	0	0
Colias philodice	1.25 GY 8.5/10	10 Y 8.5/8	+ 1.25	0	− 2
Colias philodice	1.25 GY 8.5/8	10 Y 8.5/6	+ 1.25	0	− 2
Colias philodice	1.25 GY 8.5/8	10 Y 8.5/6	+ 1.25	0	− 2
Colias philodice	1.25 GY 8.5/8	10 Y 8.5/8	+ 1.25	0	0
Colias philodice	1.25 GY 7/6	10 Y 8.5/4	+ 1.25	+1.5	− 2
Colias eurytheme (albinic)	2.5 GY 8/2	2.5 GY 9/2	0	+1.0	0
Bombus sp.*	2.5 GY 7/6	7.5 Y 7/6	+ 5	0	0
*Chrysiridia ripheus**	10 GY 6/10	10 GY 6/7	0	0	− 3
*Chrysochus auratus**	10 GY 4/8	10 GY 3/8	0	−1	0
*Agrion aequabile**	7.5 G 5/10	7.5 G 3/6	0	−2	− 4
*Agrion aequabile**	7.5 G 5/10	7.5 G 4/8	0	−1	− 2
*Agrion aequabile**	7.5 B 5/8	2.5 BG 4/8	+15	−1	0
*Morpho menelaus**	2.5 PB 5/12	5 YR 4/2	−42.5	−1	−10
*Morpho adonis**	5 PB 6/8	5 R 6/1	−30	0	− 7
*Chrysiridia ripheus**	10 RP 5/14	2.5 YR 6/11	−12.5	+1	− 3

*iridescent ◀pink

tion of the fading experiment. After vapour degreasing (McKillop and Preston, 1981b) these specimens lost the "greasy" look, showing that no real positive chroma change had taken place.

The majority of changes in hue and value occurred among the reds and blues, whereas few changes were noted in the yellow and yellow-green areas. No such pattern was observed for chroma and the frequency of change was sporadic. It was also apparent that the majority of the colour changes occurred in the early stages of the experiment.

Increased humidity had a greater effect on iridescent than on non-iridescent specimens. Under conditions of high humidity, iridescent specimens showed a greater frequency of hue, value, and chroma change than did non-iridescent specimens. It is, however, quite probable that whenever specimens were humidified, a structural change took place, thus altering colour parameters.

Pink faded most readily. It appeared that pink non-iridescent specimens dulled more than the otherwise sporadic dulling associated with the other specimens.

Conclusions

The yellowing and dulling of entomological specimens described here indicates that short wavelength radiation should be eliminated wherever possible in museums. This study indicated that it should be possible with further research to determine both the life expectancy of entomological exhibits and the maximum recommended periods of exposure for especially valuable or rare specimens.

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CARE OF SPECIMEN LABELS IN VERTEBRATE RESEARCH COLLECTIONS

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ABSTRACT—Historically, a variety of materials have been used for labelling in vertebrate collections, including metals, leather, parchment, plastics, wood, and paper. Problems related to inappropriate materials are loss of data and damage to specimens.

Methods of reducing damage to labels and to specimens include proper tying of labels and preliminary testing of all materials used in labelling. Polyester film envelopes designed to protect old or fragile labels are illustrated.

Introduction

A complementary association exists between specimens and labels in vertebrate collections. The loss of either the specimen or the label significantly reduces the value of the remaining part. Labels not only carry necessary scientific data, but may have value as original documents written by early naturalists.

Labels are damaged by inherent flaws, components of the storage environment, mishandling, and by the specimens themselves. In turn, labels may contribute to the deterioration of the specimens. Many of these problems can be prevented by careful selection of labelling materials and by careful attachment of the labels. This paper discusses these problems and the protection of fragile or damaged labels through simple conservation procedures.

Discussion

Historically, a variety of materials have been used for specimen labels, including metals, leather, parchment, plastics, wood, and paper. All these materials have some limitations and may deteriorate over time. Metal, plastic, and wooden labels may be massive and may have sharp edges and corners damaging to specimens. Metals may corrode in the presence of preparation and fumigant chemicals, high humidity, and even the organic acids volatilized by wooden storage drawers (FitzHugh and Gettens, 1971). In addition, dissimilar metals in contact (as in the case of a metal tag attached to a specimen by wire), or in indirect contact through an electrolyte (the fluid in a wet collection), may lead to corrosion of one of the metals (Promisel and Mustin, 1954). Metals may have special properties that limit their usefulness in labelling. Tin, for instance, can form a powdery allotrope at low temperatures and should not be used with specimens intended for refrigeration or freezing. Labelling on metals is restrictive and relies on stamping or inscribing limited information. Leather labels are often attached to skins intended for tanning. In the process, the leather tags are retanned and may become extremely hard and abrasive. Parchment labels are subject to distortion with changes in relative humidity and can become difficult to read as a consequence. Plastics may contain volatile additives (ultraviolet absorbers, anti-oxidants, plasticizers) potentially harmful to specimens or other labels. While no labelling material is perfect for all specimens in all situations, the material most often used, and used successfully, has been paper.

As a cellulosic fibre, paper can meet many of the criteria for a good label. Properly manufactured, it 1) takes ink and pencil manuscript and printing ink readily; 2) is available in quantity at a reasonable price; 3) does not damage the specimens if used properly; and 4) is durable. However, paper can deteriorate from the action of a variety of factors, many of which are related to, or are exacerbated by, inherent weaknesses of the paper. Paper containing acidic sizing, lignin (an organic acid), residues of bleaches, dyes, and traces of metals (which may serve as catalysts for chemical reactions), is inherently unstable (Ritzenthaler, 1983). Environmental factors, such as ultraviolet and visible light, fluctuations in temperature and relative humidity, atmospheric pollutants, pests, and exposure to acidic materials, may accelerate the deterioration of any paper (Clapp, 1978). The best paper for use in vertebrate collections is 100% cotton stock with a neutral to mildly acidic pH. We suggest a pH of 6.5 to 7.0 for label papers. Paper treated with alkaline buffers has been shown to be both permanent and durable (Barrow, 1972), however, because alkaline materials may degrade protein, these papers should not be used in direct association with vertebrate specimens. It should be noted that many papers sold as "acid-free" actually contain an alkaline reserve.

White is the preferred colour for label paper. Dyes and pigments may be fugitive when exposed to light or to

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chemicals used in the collections. All labels should have rounded corners to avoid damage to specimens. They should be printed with carbon black printing ink to prevent fading (Waters, 1936:22–23).

No matter what material has been used for a label, the manner in which it is attached to the specimen is extremely important. No abrasive or heavy substance should be used to attach labels. Natural or white cotton (or linen) thread seems to be the least harmful. To avoid damage to specimens, labels should not be tied tightly. Because specimens are hygroscopic they will swell and shrink in response to changes in relative humidity. A very tightly tied label thread can cut into skin, feathers, fur, and other tissues. The thread on the label should be long enough to permit both sides of the label to be handled and read without placing any stress on the specimen. The distance between specimen and label should be sufficient for each to rest independently of the other in storage, and short enough to keep the label from becoming entangled in other specimens or labels. Multiple labels on a specimen can be retied on a single string as shown in Figure 1. The resulting stack of labels resembles a small book whose pages can be turned with ease.

Other sources of damage to labels are inappropriate repair techniques. Staples, various glues, and pressure-sensitive tapes are the most common of these and should be avoided in caring for labels. Acceptable procedures for minor repairs and reshaping of warped or crumpled labels are given in Clapp (1978) and Ritzenthaler (1983). Both books contain bibliographies on paper conservation and list sources of suppliers for materials. We have found two repair techniques to be particularly useful. One method is the mending and the reinforcing (lining) of the blank side of labels with Japanese tissue, or acid-free, non-alkaline, buffered mending tissue, and wheat starch paste. In addition, weak or torn labels with data on the back can be repaired with heat-set tissue. Heat-set tissue is pure cellulose lens tissue coated on one side with an acrylic resin. It is applied to damaged paper with a tacking iron (Roberts and Etherington, 1982:130). Although this procedure is not readily reversible, it allows labels to continue as working documents because one can read through, and write over, the repair.

Another technique for protecting fragile or damaged labels is shown in Figure 2. These are designs for Mylar™ envelopes and encapsulation. Mylar (a registered trademark of E. I. duPont de Nemours & Co., Inc.) is a clear, stable polyester film containing no plasticizers or other additives. We found that 3-mil Mylar worked well for our designs because it is fusible and stiff enough to support a label. It is also lightweight and should not add much weight or bulk to any label. The polyester film can be sealed by high heat, by ultrasound, or by a special adhesive tape (United States Library of Congress, 1980). Heat or ultrasound sealing machines are expensive and practical only for large-scale operations, and we cannot predict the response of the adhesive to the variety of fumigants used in vertebrate collections. Hence, our envelopes were sealed by running the tip of a small soldering iron along a metal straightedge positioned over two pieces of film. The drawback to this method is that the envelope seals are not particularly strong. They will, however, withstand reasonable handling.

The first two envelope styles shown in Figure 2 are intended for repaired or fairly strong labels which must be accessible for future notations. Style C is a special flap envelope for fragile or unrepaired labels which may be removed at times for additional notes. Style D is full

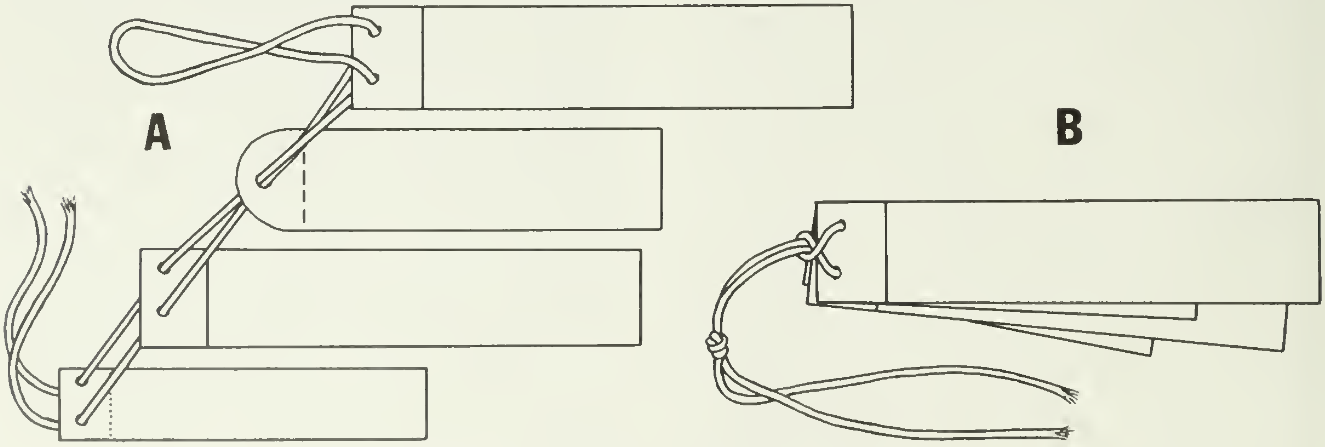

Fig. 1. Systematic method for tying multiple labels.

A. Method for stringing the labels together.

B. Completed stack of labels with single attachment to specimen.

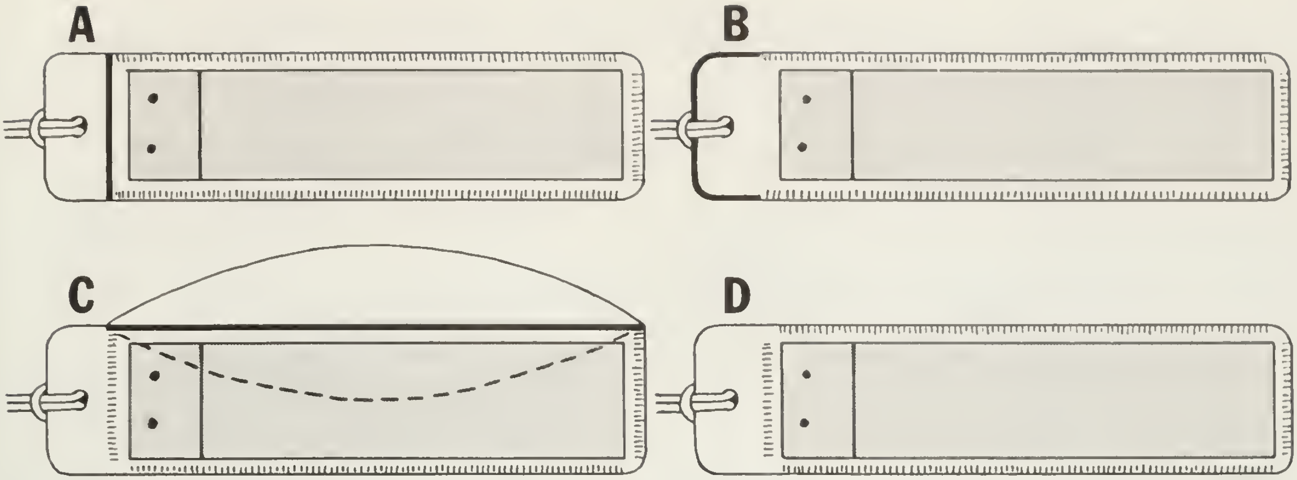

Fig. 2. Designs for Mylar envelopes and encapsulation. Bold lines indicate openings. Tick marks indicate heat bonding of the two pieces of mylar.

A. Envelope for reasonably durable labels that must be accessible for future notations.

B. Variation on style A.

C. Envelope for fragile and unrepaired labels.

D. Mylar encapsulation for stabilized or fully repaired labels that will not receive additional notations.

encapsulation and may be most suited for old original labels that have been properly repaired or are in good condition. All styles should have the corners rounded to break the seal, to permit air exchange around the label, and to protect the specimen from sharp corners on the film. For all styles, the catalogue number of the specimen should be inscribed on the envelope with a stylus. Because the label itself is not directly tied to the specimen, an inscribed catalogue number on the envelope will allow reassociation of the specimen and data if the label is removed.

In addition to protecting paper labels, Mylar encapsulation can be used for metal labels to limit the transfer of corrosion products to the specimens and to protect the metal surface from handling. Rough leather or wood labels can be encapsulated also. Red labels for type specimens and other coloured labels can be tested for stability by passing a dry cotton swab across the surface. If the colour comes off on the swab, the label should be placed in a Mylar envelope to protect the specimen from staining. When grease is migrating down the string onto a label, either the flap envelope or encapsulation styles will protect the label from this grease.

Mylar encapsulation is not a solution for all label problems. For instance, parchment labels may have ink riding on the surface and the static electricity in Mylar could damage the data. Problems with parchment labels and indeed, complex problems with *any* labels, should be referred to a trained conservator.

In rare situations it may be desirable to remove a supplemental label that is damaging the specimen or other labels, particularly if the destructive label only duplicates information on other labels. If this is the problem and no other solution is available, proper procedures for removing the label should be followed. Data on the removed label should be double-checked to insure the information is accurately duplicated on other labels. Because labels provide a written history of the specimen as well as a possible indicator of relationships with other specimens, *labels should never be discarded*. Instead, place the label in a file envelope with all associated data about the specimen. The removed label and the remaining specimen and labels should be cross-referenced in the written and computerized records of the collection so that all parts can be used if necessary.

Summary

Most of the problems encountered with labels in vertebrate collections could be prevented through care in choosing labelling materials and in attaching the labels. A good label material will not harm the specimen or other labels and will be reasonably stable and durable in the collection environment. If paper labels are used, good quality paper is required. Any new shipment of labels should be tested at random to check the pH and should be tested in all fluids and fumigant chemicals used in the collection to check durability.

Problems with extant labels can be minimized through retying of multiple labels in a systematic fashion, through minor paper repair techniques, and through the use of polyester film envelopes or encapsulation. These procedures can reduce damage to the specimens and increase the useful life of the labels in vertebrate collections.

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FORMULATION, IMPLEMENTATION, AND EVALUATION OF COLLECTIONS MANAGEMENT PROGRAMS

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ABSTRACT—A collections management program associates specimens and data, maintains specimens in optimum condition, and makes the collection available for study. Standard policies and procedures should cover accession, cataloguing, loans, and information retrieval.

Introduction

Tradition abounds in the management of natural history collections; most collections managers follow procedures and systems that were established long ago and are assumed to be the best for the care of the specimens. In many cases, new and better methods are available.

Much of collections management involves the obvious (or what should be the obvious), and for that reason there is often a lack of written policies, procedures, and directions as to how the collection should be managed (Malaro, 1979). This paper provides a framework for formulating an efficient collections management program and evaluating its effectiveness.

Functions of Collections Management

Collections management has three main functions: 1) permanent association of individual specimens with the relevant data concerning their collection and status; 2) maintenance of the specimens in optimum condition, thereby preserving the maximum amount of information obtainable from each specimen and safeguarding all data related to that specimen; and 3) making the specimens and data easily available to qualified workers.

The Responsibility of the Collections Manager to the Curator

In general, the curator directs the growth and management of the collections and arranges for and allocates the necessary funds for these processes (Colbert, 1958). The collections manager has the responsibility for the routine functions of maintenance and growth of the collection, and works with the curator to solve problems and establish policy (Laub, 1985).

The Responsibility of the Collections Manager to the Collection

The primary responsibility of the collections manager is the proper care and maintenance of the specimens. As so well stated by Yochelson (1969), "Proper curation is a thankless task which is generally shirked. Shame on all of us. If a [specimen] is worth keeping, it is worth keeping well." There will be times when the collections manager will disagree with the administrator of the institution or even the curator as to what is proper care for the collection. However, a good collections manager should make every effort to convince them of the need to do things a particular way.

The collections manager must remember that while collections and museums are permanent, researchers and technicians are rather ephemeral beings. Their mistakes become part of the collection, too.

Establishing and Implementing a Collections Management Program

The following criteria must be met to establish a collections management program in order to maintain the specimens in the best possible condition:

1) *Keep procedures simple and standardized:* Procedures should be easy to teach to others, and easy to resume if interrupted. Remember that simple procedures are less likely to be ignored or misunderstood than complex ones.

2) *Maintain the collection in the best possible condition:* This does not mean simply to maintain it in an *adequate* condition, but to think ahead to the long-term use and conservation of the collection before policies and procedures are implemented.

3) *Protect the integrity and completeness of the data and cross-reference files:* Remember that errors will always accumulate. Computerized data management systems will make finding errors much easier, but will also make it easier to perpetuate errors in the collection.

4) *Fill requests for specimens and data promptly:* Recognize your responsibility to the scientific community to provide access to the collection and data.

The Collections Management Program

The management program must be tailored to the peculiarities of the collection and institution, but should

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cover the following areas:

1) *Accession Policy*—The application of the accession policy begins in the field with the acquisition of the collection. What are your requirements for collecting and import/export permits, standards of field documentation, procedures for preservation, etc.?

2) *Standard Format and Procedure for Data Entry*—Data standards help to ensure the accuracy of the collection records (Chenhall and Homulos, 1978; Humphrey and Clausen, 1977). It is far easier to trace errors of data entry when the format is clearly defined. When mistakes are made at any stage of cataloguing or numbering specimens, they will be easier to resolve if a standard procedure has been followed.

3) *Loan Policy*—This should specify who can borrow specimens and for how long, the size of loans, what specimens can be loaned, and procedures for recalling overdue loans.

4) *Progressive Maintenance Schedule*—It is a common mistake to think that once a specimen is in the collection, it requires no further attention. The entire collection must be inspected carefully on a regular basis for evidence of deterioration, presence of vermin, or degradation of preservatives. To make this task both less burdensome and more effective, establish a timetable so that the collection is checked over gradually but completely during the course of each year.

5) *Record Management*—This has become much easier with computers, but don't jump into a system too quickly and discover that it is unsuitable for your collection. Examine your collection needs and patterns of usage before buying hardware or software (Sarasan and Neuner, 1983). Computerization should give you an information-retrieval system that will sort by such categories as geographic origin, taxonomic unit, and other forms of supporting material (tapes, slides, and so forth). A mechanism for evaluating collection use will not only tell you where you can improve the system, but will also provide useful data for grant applications and justification of budget requests.

How to Evaluate the Collections Management Program

A yearly review of the collections management program is essential. The review process should consider these questions:

1) Are the specimens in the collection maintained in the best possible condition?

2) Does cataloguing keep up with incoming accessions, or is too large a backlog of material accumulating?

3) Are specimens incorporated into the collection on a regular basis?

4) Is the preparation of cross-reference files keeping up with cataloguing? The ideal lag time should be no more than 1000 to 1500 catalogue entries.

5) Is current nomenclature used in the collection records and on specimen labels?

6) How long is the response time to requests for data? Are the cross-reference files adequate for rapid response to requests for data, or is there a need to establish other files for effective use of the collection?

7) What is the turn-around time for loan requests? If it is more than two weeks, examine the procedures and use of personnel carefully.

8) Has the growth of the collection met expectations?

9) Are the collections management personnel busy, or are they too busy, and thus behind in their work?

10) Is the scientific community aware of the collection? Evaluate your user records to see if some parts of the collection are underused. If so, what can be done to correct this?

Remember that the nature of a collections management program should be progressive and dynamic. Evaluate it frequently, and fine tune it as the collection grows and the demands on it change.

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PROGRESS IN THE CURATION OF NATURAL HISTORY COLLECTIONS AT THE NEW BRUNSWICK MUSEUM

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ABSTRACT—In 1982 the New Brunswick Museum, with partial financial assistance from the National Museums of Canada Museum Assistance Programme, embarked on a programme to upgrade storage of natural history collections. Storage cabinets were purchased to accommodate the overcrowded collection; research collections were separated from educational and display materials; transfer of wet collections from 10% unbuffered formalin to 45% isopropyl alcohol was initiated; and cataloguing procedures were modified. It is expected that this programme to improve the curation of the collections will continue for another three to five years.

Introduction

Before 1982, many of the natural history collections at the New Brunswick Museum (NBM) were severely overcrowded and in danger of being damaged. Access to the material for research was difficult at best. Since then, a programme of upgrading the storage facilities of the natural history collections and preparing associated data for computer entry has been underway. Funded in part by the National Museums of Canada with a $38 000 grant provided under the Museum Assistance Programme (MAP), this project has already resulted in a major reorganization of the zoological collections and has increased the accessibility of material to researchers. The programme has also encouraged museum staff to solicit well-documented collections from individuals and government agencies, resulting in the acquisition of good series of useful specimens, particularly small mammals (Fig. 1). Here I briefly describe the natural history collections housed at the New Brunswick Museum and the changes that have taken place in the reorganization of these collections over the past three years.

Development of the Science Collections

The New Brunswick Museum, incorporated in 1929, is the direct descendant of one of the first public museums in Canada, which was opened in Saint John in 1842 by Dr Abraham Gesner. The Museum today encompasses the fields of fine art, Canadian history, and natural science, but it is in the latter area that the institution had its beginnings. Those with an interest in the history and development of the institution should consult Squires (1945). Gorham (1978) and Hipperson (1983) have summarized the development of the science collections.

Although portions of the natural science collections date from the mid to late 19th century, many of the collections were not organized as provincial systematic collections until 25 years ago. Through the unflagging efforts of S. W. Gorham, particularly between 1965 and 1975, the bulk of the material that has formed the nucleus of the collections of fishes, amphibians, reptiles, birds, and mammals was assembled. Specimens collected by early naturalists, including individuals associated with the New Brunswick Natural History Society (1862–1932), have been incorporated into the present collections and form an invaluable record. The ornithological collection in particular is rich in skins and eggs collected in the late 19th and early 20th centuries. Against this backdrop of over a century of collecting, the present programme to upgrade the storage of the New Brunswick Museum's natural history collections was undertaken in preparation for renewed collections growth.

Progress in Curation

Table 1 summarizes natural history collections currently housed at the New Brunswick Museum. To date, most of the effort to upgrade and reorganize storage has been directed towards the zoological collections. We hope that shortly a paleontologist will be contracted to organize the paleontological collection. The botanical collection was well organized and not severely overcrowded before this project began, largely as a result of the efforts of previous curators A. W. Squires and D. S. Christie.

Before 1983, separate zoological research and teaching/display collections were not maintained at the New Brunswick Museum. All specimens, whether collected for research, teaching, or display, were catalogued and housed together. This situation created problems in the handling and organization of the collections. To ensure

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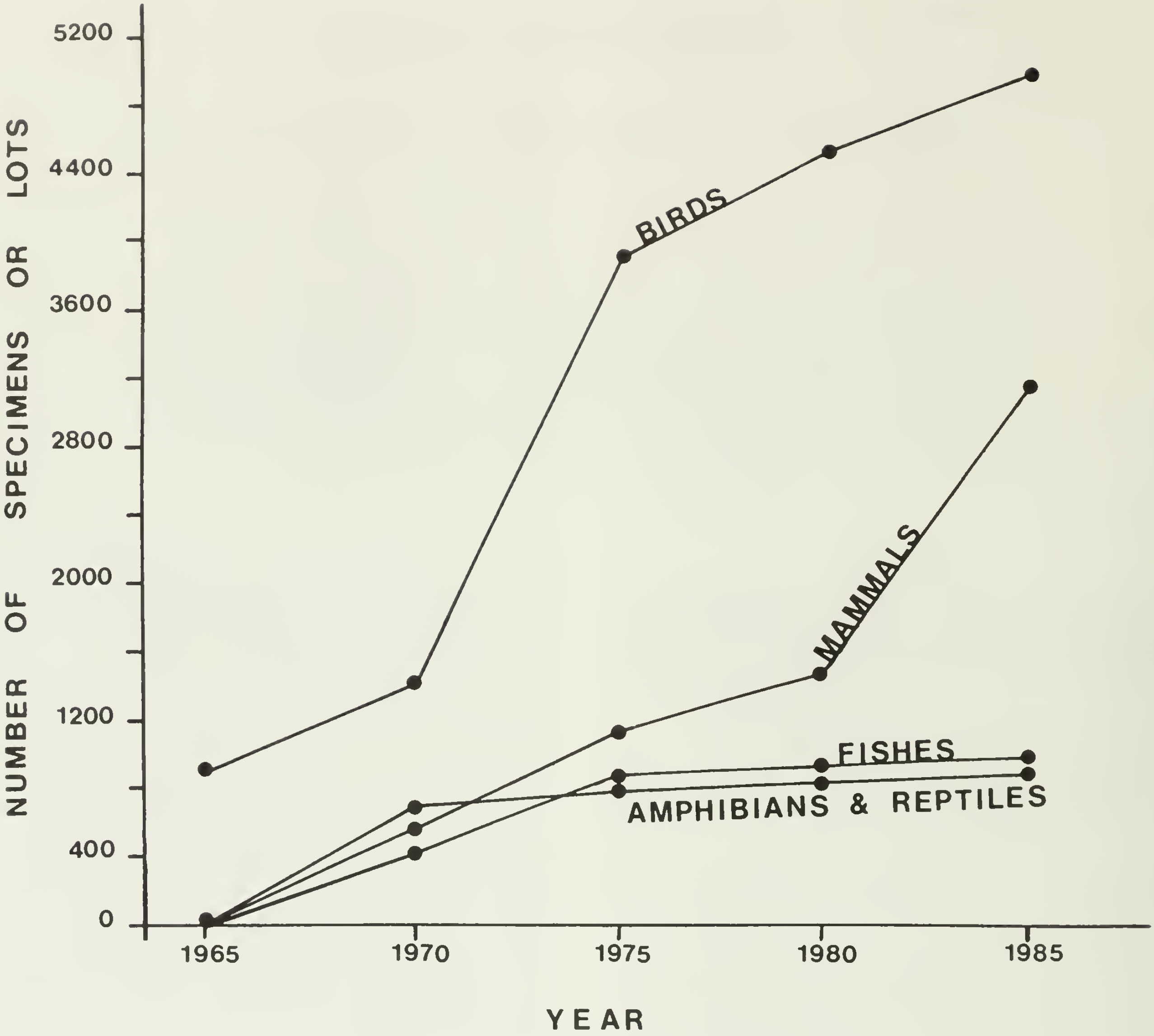

Fig. 1. Growth of Vertebrate Collections at the NBM 1965–1985.

Table 1 **Number of specimens or lots in the natural history collections at the New Brunswick Museum**

Collection	Number of Specimens or Lots
Rocks, Minerals, Fossils	±40 000
Vascular Plants	20 431
Invertebrates (exclusive of insects)	± 1 500
Insects	±13 000
Fishes	1 089 lots
Amphibians and Reptiles	1 047 lots
Birds	5 189
Mammals	3 516

that acquisitions to research collections are permanently preserved, the handling, shipping, and exposure to light of specimens must be minimized. These efforts, in many respects, contradict the objectives of assembling teaching and display collections, which students and museum visitors are expected to handle and view on a continuing basis. Under such circumstances, damage and deterioration of specimens is inevitable and the useful life of teaching or display material, where original specimens are used, must be considered relatively short. For these reasons, starting in 1983, the zoological collections were divided into separate research and teaching/display sections. Material of no scientific value, but previously catalogued, was deaccessioned (within the framework of the institutional collections policy) from the research collections and either placed in the teaching/display collection or discarded. So far, deaccessioned material has been taken entirely from the vertebrate collections, mostly mounted birds.

Over the past two years, 32 skin cabinets have been purchased from Dompro Ltd of Saint-Laurent, Quebec, to accommodate the severely overcrowded bird and mammal collections and to handle anticipated growth over the next two decades. Vertebrate catalogues, previously a few penciled lines in a steno pad, have been standardized and data sheets compatible with computer entry are now in use for most New Brunswick Museum zoological collections. The fish and herpetological ranges have been nearly doubled by the addition of new steel shelving. All wet collections had previously been stored in 10% unbuffered formalin, but new collections are now being stored in 45% isopropanol and old collections are gradually being transferred into isopropanol. The collection of large fish has been moved into 45% isopropanol and over the next two years, as funds permit, the remainder of the fish and herpetological collections will be transferred.

Much of the invertebrate material in the collection (excluding insects) has now been sorted. This includes a sizable collection of freshwater unionids, mostly from the central and eastern United States, a series of late 19th century collections of freshwater and terrestrial gastropods from southern New Brunswick, and a small but diverse collection of marine invertebrates collected in the Bay of Fundy. The intention is to catalogue invertebrate material (exclusive of insects) over the next year, with the hope that it will provide the nucleus for growth of these collections. As well, one might hope that such growth will stimulate research on the terrestrial and freshwater invertebrate fauna of the province, which remains in many respects largely unknown (Clayden, McAlpine, and Guidry, 1984). The insect collection is not large, but the 13 000 specimens it does contain are historically significant, having been collected mostly in southern New Brunswick in the late 19th and early 20th centuries by one-time provincial entomologist and New Brunswick Museum science curator W. F. McIntosh.

Initially, the programme to upgrade storage was planned as a two-year project. It has, however, initiated a large-scale reorganization of all NBM natural history collections that will probably continue for another three to five years. We hope that the outcome will be a strong commitment to the long-term maintenance of the provincial research collections in the natural sciences, an increase in investigations on the flora and fauna of the province, and a greater diversity of material for use in public programmes and gallery displays.

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HEALTH AND SAFETY IN NATURAL HISTORY MUSEUMS: AN ANNOTATED READING LIST

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Introduction

The preparation, preservation, storage, and display of natural history specimens exposes the museum worker to a variety of materials and situations, many of which, alone or in combination, are potentially harmful. Unlike industrial workers, the museum worker is rarely exposed to the threat of large doses of a single compound. Rather, museum workers tend to have continuous low-level exposure to several substances which may have synergystic effects. As a result, museum workers often have chronic health problems rather than the dramatic injuries experienced in the industrial context. Literature on materials hazards is scarce in the natural history fields. Most of the references in the following reading list are more readily associated with conservation of manufactured artifacts, with theatre arts, or are from industrial and medical journals. Duplication of subject matter is deliberate as not all references are readily available. The list is by no means exhaustive and the authors would welcome additions.

Sources of Health and Safety Information

American Conference of Governmental Industrial Hygienists
Publications Section
6500 Glenway Ave., Bldg D-7
Cincinnati, Ohio 45211, U.S.A.
Telephone (513) 661-7881
Offers an extensive catalogue of health and safety related publications.

Canadian Centre for Occupational Health and Safety
250 Main Street East
Hamilton, Ontario L8N 1H6
Telephone (416) 523-2981
Information and Advisory Service invites inquiries by telephone or mail, having to do with concerns about workplace safety and health.

Center for Occupational Hazards
5 Beekman Street, New York, NY 10038
Telephone (212) 227-6220
A national clearing-house for research and information on health hazards in the arts. Services include: art hazards courses, lectures and consultations; Art Hazards News, a four-page newsletter published 10 times per year; a long list of data sheets, books, and pamphlets available.

Industrial Accident Prevention Association (IAPA)
2 Bloor Street West, 31st floor
Toronto, Ontario M4W 3N8
Telephone (416) 965-8888
Resource library provides information on a wide variety of safety and health topics; circulates "Library News", listing recently received publications on the practical aspects of hazards and their control in the workplace.

National Institute for Occupational Safety and Health (NIOSH)
NIOSH Publications Dissemination
Division of Technical Services
4676 Columbia Parkway
Cincinnati, Ohio 45226

Material Hazards Data Sheets—available for all chemicals from the supplier. Contain chemical composition as well as information on toxicity, threshold limit values, flammability, and emergency first aid treatment.
Various library computer data bases include references on health and safety.

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EDWARDS, S. R., B. M. BELL, and M. E. KING
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Results of a case study on levels of naphthalene, paradichlorobenzene, mercury, and arsenic in the storage area of the City of Bristol Museum. Concludes that mercury levels are not serious but that arsenic levels may be very high in many specimens.

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1982 Thymol and o-phenyl phenol: safe work practices. New York, Center for Occupational Hazards.
Includes sketch designs for a thymol fumigation chamber.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

1981 Ethylene oxide (EtO): evidence of carcinogenicity. National Institute for Occupational Safety and Health (NIOSH) Current Intelligence Bulletin 35 (May 22, 1981). 22 pp.

ONTARIO MINISTRY OF THE ENVIRONMENT

1981 Pesticides safety handbook. Toronto, Pesticides Control Section. Pollution Control Branch, Ontario Ministry of the Environment. 60 pp.
Classification of pesticides—toxicity, safe use, and symptoms and treatment following contact. Written for agricultural and industrial use.

SARAN, C., L. L. SIMS, P. M. HUGHES, and S. A. ADAM

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SOLVENTS

ANONYMOUS

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1984 Reproductive hazards of glycol ethers. United Auto Workers Health and Safety, March–April 1984.
Glycol ethers are used as solvents for paints, inks, nitrocellulose, pigments, and leather finishes and are also used in brake fluids, gasoline, varnish removers, and other products. They are suspected of being injurious to the reproductive health of both males and females at levels below the current OSHA standards. Other effects of long- and short-term overexposure are discussed.

CENTER FOR OCCUPATIONAL HAZARDS

1981 The hazards of solvents. New York, Center for Occupational Hazards.
Discusses common solvents by class, listing organs affected, symptoms of poisoning, and fire hazards.

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1980 The handling, hazards and maintenance of heavy liquids in the geological laboratory. United States Department of the Interior, Geological Survey Circular 827.

MANUFACTURING CHEMISTS ASSOCIATION

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PASCOE, M.

1980 Toxic hazards from solvents in conservation. The Conservator 4:25–28.
An excellent summary of solvent hazards giving threshold limits, short-term exposure limits, boiling point, flash point, and specific hazards to health and safety.

ROSSOL, M.

1981 Paint removers: hazards and precautions. New York, Center for Occupational Hazards.
Outlines the health and safety hazards of paint remover solvents, including methylene chloride, toluene, methanol, ethanol, acetone, mineral spirits, and benzene.

STEVENS, A. M.

1984 Search and destroy mission finds hazards of flammable liquids. Research and Development, February 1984, pp. 138–141.
Discusses the fire hazards of vapours from volatile liquids and outlines safe storage and disposal practices.

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CENTER FOR OCCUPATIONAL HAZARDS

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1979 Artist Beware. New York, Watson-Guptill. 378 pp.
An excellent reference text outlining many hazards relevant to natural history workers.

1985 Health hazards manual for artists. 3rd ed. New York, Nick Lyons Books. 100 pp.
Includes sections on how art materials affect the body, hazards of various media, safety in the studio, sources of safety equipment, and an extensive bibliography.

McCRONE, W.

1984 Status of Aroclor mounting media. Letter in Art Hazards News 7(8):2.
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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

1977 Criteria for a recommended standard: occupational exposure to fibrous glass. Washington, D.C., U.S. Department of Health, Education and Welfare. 189 pp.

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